MURPHY CREEK PROJECT
ENVIRONMENTAL ASSESSMENT
WATER QUALITY STUDY

Prepared for:

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B.C. HYDRO

This impact assessment is based on the "Murphy Creek Project Engineering Description" prepared in November 1982. Since that time, ongoing planning and design studies have resulted in some changes that would affect the project description. The principal changes are as follows:

- In-service date has changed from 1993 to 1995.

- Installed capacity has changed from 300 MW to 275 MW.

- Small changes to the design and locations of shoreline protective works.

- Daily reservoir level fluctuations limited to 2.0 m during March, April and May (previously March and April).

The above changes have been incorporated in the report only where they would affect the results of the impact assessment.

TABLE OF CONTENTS

1.0	**SUMMARY**		1
2.0	**INTRODUCTION**		6
	2.1	**Background**	6
	2.2	**Study Objectives**	7
3.0	**PROJECT DESCRIPTION**		9
4.0	**ENVIRONMENTAL SETTING**		12
	4.1	**Inventory of Water Use**	12
	4.2	**Chemical Characteristics**	14
		4.2.1 Nitrogen	15
		4.2.2 Phosphorus	18
		4.2.3 Dissolved Gases	21
		4.2.4 Dissolved Oxygen	21
		4.2.5 Turbidity, Suspended Solids and Colour	23
		4.2.6 Trace Metals and Compounds	25
		4.2.7 Foam	25
		4.2.8 Taste and Odour	27
		4.2.9 Fish Flavour Impairment	27
		4.2.10 Toxicity	27
	4.3	**Thermal Stratification**	28
		4.3.1 General	28
		4.3.2 Arrow Lakes Reservoir	29
	4.4	**Effluent Sources and Quality**	31
		4.4.1 General	31
		4.4.2 BC Timber Ltd.	33
		4.4.3 Municipal Effluents	37
	4.5	**Agricultural and Recreational Uses**	38
5.0	**IMPACT ASSESSMENT**		40
	5.1	**Construction Impacts**	40
		5.1.1 Literature Review	40
		5.1.2 Murphy Creek Dam Construction	43
		5.1.3 Hugh Keenleyside Dam Construction	43
		5.1.4 Suspended Solids During Murphy Creek Dam Construction	53
	5.2	**Operational Impacts**	54
		5.2.1 Nitrogen	54
		5.2.2 Phosphorus	55
		5.2.3 Colour	55
		5.2.4 Toxicity	58

TABLE OF CONTENTS (Continued)

		Page
5.2.5	Dissolved Gases	58
5.2.6	Dissolved Oxygen	58
5.2.7	Thermal Stratification	60
5.2.8	BC Timber Ltd. Effluent Dispersion	61
5.2.9	Suspended Solids/Turbidity	67
6.0 MITIGATION		68
6.1	**Construction Mitigative Measures**	68
6.2	**Operational Mitigative Measures**	69
7.0 RECOMMENDATIONS		70
8.0 REFERENCES		71

APPENDICES

1 Water & Effluent Quality Data

2.1 Analysis of Arrow Lakes Reservoir to Determine Solar Heat Flux Contribution
2.2 Potential Oxygen Sag
2.3 Field Notes - BC Timber Ltd. Plume Study
2.4 Field Notes - Arrow Lakes Reservoir Study

3 Columbia River Water Quality and Flow Data During Construction of Hugh Keenlyside and Revelstoke Dams

4 Terms of Reference

LIST OF TABLES

		Page
Table 4.1	Existing Nitrogenous Concentrations And Loadings	16
Table 4.2	Existing Nitrogenous Concentrations And Loadings	17
Table 4.3	Phosphorus Concentrations and Loadings	19
Table 4.4	Phosphorus Concentrations and Loadings	20
Table 4.5	Summary of Dissolved Oxygen Levels in Study Area	22
Table 4.6	Dissolved Oxygen At Confluence of Columbia and Kootenay Rivers and at Birchbank	24
Table 4.7	Average Values of Trace Metals and Compounds In Columbia and Kootenay Rivers	26
Table 4.8	Arrow Lakes Reservoir Heat Flux	30
Table 4.9	Heat Flux Inputs to Arrow Lakes Reservour	30
Table 4.10	Effluent Sources and Average Ouality	32
Table 4.11	BC Timber Ltd. Effluent Characteristics, Permit Requirements and 1977 Level A Objectives	35
Table 4.12	Field Study Conditions - BC Timber Ltd.	36
Table 5.1	Information Retrieval Data Bases	41
Table 5.2	Preconstruction Levels of Suspended Solids: Sept. 1963 - April 1965	45
Table 5.3	Columbia River Velocities (m/sec.)	46
Table 5.4	Suspended Solids at Castlegar During Hugh Keenleyside Dam Construction May 1965 - December 1966	48
Table 5.5	Turbidity of Tadanac Untreated Water	49
Table 5.6	Predicted Suspended Solids Concentrations for Stations Downstream of Castlegar During Hugh Keenleyside Dam Construction: May 1965 - December 1966	50

LIST OF TABLES (Continued)

		Page
Table 5.7	Predicted Downstream Levels of Suspended Solids During Construction of Murphy Creek Dam	56
Table 5.8	Suspended Solids Criteria	57
Table 5.9	Reduction in Oxygen Concentration Downstream From BC timber Ltd. Due to Organic Matter Demand at Extreme Low River Flows and 20°C.	62
Table 5.10	Comparision of Heat Fluxes to Surface Layer of Reservoir in July - August	63
Table 5.11	Calculated Effluent Dilutions 5000 M from Diffuser (F = 16.3)	66

LIST OF FIGURES

3.1	Proposed Murphy Creek Dam
3.2	Murphy Creek Project - Columbia River Diversion Plans
3.3	Murphy Creek Project - Construction Schedule
4.1	Period Differences in Heat Content of Arrow Lakes Reservoir
4.2	Comparision of Advective & Solar Heat Fluxes to Arrow Lakes Reservoir
5.1	Concentration of Suspended Solids vs Flow at Castlegar during Hugh Keenleyside Dam Construction
5.2	Concentration of Suspended Solids and Flows at Castlegar vs Activity Associated with Hugh Keenleyside Dam Construction
5.3	Concentrations of Suspended Solids and Flows Below Revelstoke Dam vs Activity Associated with Revelstoke Dam Construction
5.4	BC Timber Ltd. Plume Model Distance D/S Plume Emerges vs River Flow Elevation 424 m
5.5	BC Timber Ltd. Plume Model Distance D/S Plume Emerges vs River Flow Elevation 420.5 m
5.6	BC Timber Ltd. Plume Model Distance D/S Plume Emerges vs River Flow Elevation 419.8 m
5.7	BC Timber Ltd. Plume Model Distance D/S Plume Emerges vs River Flow Elevation 424 m
5.8	BC Timber Ltd. Plume Model Dilution at Plume "Boil-Up" vs River Flow Elevation 424 m
5.9	BC Timber Ltd. Plume Model Dilution at Plume "Boil-Up" vs River Flow Elevation 420.5 m
5.10	BC Timber Ltd. Plume Model Dilution at Plume "Boil-Up" vs River Flow Elevation 419.8 m
5.11	BC Timber Ltd. Plume Model Dilution at Plume "Boil-Up" vs River Flow Elevation 417 m
A1	Columbia River above Birchbank, Effluent Discharge & River Sample Station Locations

LIST OF APPENDICES

Appendix 1	Water & Effluent Quality Data	
Appendix 2	A2.1	Analysis of Arrow Lakes Reservoir to Determine Solar Heat Flux Contribution
	A2.2	Potential Oxygen Sag
	A2.3	Field Notes - BC Timber Ltd. Plume Study
	A2.4	Field Notes - Arrow Lakes Reservoir Study
Appendix 3	Columbia River Water Quality and Flow Data During Construction of Hugh Keenleyside and Revelstoke Dams	
Appendix 4	Terms of Reference for Environmental Studies for the Proposed Murphy Creek Hydroelectric Project	

1.0 SUMMARY

This report presents the results and conclusions of a comprehensive environmental impact evaluation on Columbia River water quality in relation to proposed hydro-electric development by B.C. Hydro in the vicinity of Murphy Creek. This evaluation considers all proposed project actions including construction, reservoir clearing, dam, powerhouse and operation of the power plant. The report presents an inventory of existing water quality in the study area from available data and from on-site investigations. Furthermore, the report presents qualitative and quantitative evaluations of impacts both adverse and beneficial. Mitigation opportunities are discussed and recommendations are tabled for follow-up studies. The report represents one of several related study subjects commissioned by B.C. Hydro and as such should be read in conjunction with separate reports by other consultants on fish and aquatic habitats and downstream water use.

Field and office studies were carried out during 1980 and 1981. Extensive evaluation of existing technical data provided the principal basis for water quality impact prediction. The report was updated in December, 1982 and February, 1984. A comprehensive computer literature search was undertaken to augment the existing data and to draw upon previous experiences associated with other hydro electric project developments.

The significant findings of the study are as follows:

Effluent Sources

Major point source effluent discharges in the study area include the BC Timber Ltd. mill, the City of Castlegar waste stabilization pond and activated sludge plant and the Selkirk College aeration lagoon (BC Timber Ltd. was formerly called Canadian Cellulose Co. Ltd. and was frequently referred to as Celgar or Cancel). The BC Timber Ltd. discharge represents 99% of the 5 day biochemical oxygen demand (BOD_5) and suspended solids loadings, 92% of the nitrogen and 94% of the phosphorus loadings to receiving water in the study area. B.C. Ministry of Environment have identified several water quality impacts from the BC Timber Ltd. discharges including sublethal

stress on aquatic life, colour, taste and odour. The company is considering an expansion of production and installation of an aerated lagoon. The proposed treatment will not reduce present colour levels, however, some reduction in foam production may be anticipated.

Existing Water Quality

Water in the Columbia River in the vicinity of the proposed Murphy Creek Dam is of good quality.

Water concentrations of the various nitrogen species including ammonia nitrogen, nitrate and nitrite in the study area meet Federal and Provincial guidelines for drinking water and protection of aquatic life. Similarly, total phosphorus concentrations meet guidelines.

Dissolved gas supersaturation occurs downstream of the Hugh Keenleyside Dam when water is discharged over the sluiceway causing air entrainment as the water plunges into the energy dissipator. Supersaturation decreases downstream due to the inflow of the Kootenay River.

Existing dissolved oxygen concentrations in the study area are near saturation and there is no appreciable sag in the reach from BC Timber Ltd. discharge to Birchbank.

Concentrations of suspended solids and turbidity in the Columbia River are low and typical of mountain drainage basins. Upstream, suspended solids probably settle in the headponds of the Brilliant and Hugh Keenleyside dams. Slight, although not ecologically significant, increases in river water colour occur downstream of the BC Timber Ltd. mill.

Trace compound concentrations are low although cadmium, cyanide and phenol concentrations do not meet surface water quality objectives. Phenol exceeds drinking water objectives.

Future Water Quality

The proposed construction of the Murphy Creek Dam is in the dry and would not include disposal of excavated material in the river. As such, it is probable that most suspended solids and turbidity generated at the damsite would originate from runoff caused by local precipitation events in the vicinity of the construction site. In addition, erosion in the Murphy Creek watershed represents a potential source of suspended solids as it is being considered as a possible source of till material.

The increase in turbidity and suspended solids concentration from construction probably would be observed from Year 1 (one year after project approval) to Year 5.75. Channel excavation is expected to last from Year 1 through the third quarter of Year 5. The construction and removal of the cellular coffer-dam and the construction of rockfill dykes would occur within this time period. Removal of the powerhouse coffer-dam in the second and third quarter of Year 5 would be the last construction activity likely to cause increased turbidity and suspended solids.

During construction of the Hugh Keenleyside Dam suspended solids concentrations measured at Castlegar increased from an average of 1.2 to 12.7 mg/L and the upper 97.5th percentile concentration was 32.0 mg/L. Similar increases in suspended solids concentrations may occur immediately downstream of Murphy Creek Dam during periods of intense construction activity and during significant local precipitation events.

Operation of the Murphy Creek Dam is interdependent upon operation of the Hugh Keenleyside Dam. At present two operating scenarios are under consideration. Regime 1 operation assumes that the reservoir mean level would be lowered from elevation 424 m to 418 m on average during the period February to April inclusive to permit evacuation of Arrow Lakes Reservoir. Regime 2 operation presumes that the mean water level would remain constant at 424 m throughout the year for most years. Major replenishment of the reservoir would occur from upstream sources of high water quality.

Existing nitrogen and phosphorus water quality would not change significantly and should represent average concentrations entering the proposed reservoir.

The reservoir, under either operating scenario, would moderately improve the dispersion of the BC Timber Ltd. effluent plume by increasing initial surface dilution and reducing ponding action at the confluence of the Kootenay River during critical low-flow periods of the year.

Dissolved gas supersaturation presently results in the Columbia River from the use of the spillway at Hugh Keenleyside Dam. For future operating conditions, only 1.5% (Regime 1) up to 3% (Regime 2) of the total flow would pass over the spillway in comparision to the present 68% of the flow. Gas supersaturation downstream from the Keenleyside Dam should be of minimal concern under the future operating regimes.

As the proposed normal operating mode of the Murphy Creek Dam would be underflow through the turbines or under radial spillway gates, there would be little opportunity for air entrainment. Supersaturation downstream of the proposed dam should not be significantly altered from present conditions.

A theoretical reduction in dissolved oxygen concentrations downstream of BC Timber Ltd. of up to 2 mg/L could occur under existing loadings and extreme low flows. These are not likely to cause depletions below B.C. Water Quality Guidelines.

The construction of the dam at Murphy Creek would not significantly affect the thermal characteristics of the Columbia River.

The BC Timber Ltd. effluent plume would probably surface less than 200 m downstream of the diffuser. Dispersion of the plume should improve with installation of the new dam.

Mitigation

To minimize increases in suspended solids concentration, it is recommended that the construction area of Murphy Creek Dam should be designed as a closed system in which water used in construction processes is recycled. A designed settling pond could be built to intercept all extraneous process effluents before discharge to the Columbia River.

In addition, the potential for a downstream suspended solids plume can be minimized by directing all storm drainage from the construction area to discharge upstream of the dam. This would provide improved mixing and dispersion as water passes the dam.

The potential for gas supersaturation downstream of the Hugh Keenleyside Dam could be greatly reduced under proposed Regime 1 and 2 operating conditions. Flows passing over the spillway at the Keenleyside Dam, which cause supersaturation, would be reduced from the 68% of the present total flow to 1.5% and 3% under Regime 1 and 2 operations respectively.

Finally, it is recommended that B.C. Hydro undertake a comprehensive baseline and construction water quality monitoring program of the Columbia River above and below the proposed Murphy Creek Dam. The program should be conducted at least weekly and should include periods of intense local precipitation. The program should be initiated two years prior to commencement of construction and continue annually during construction and terminate after two years of dam operation.

2.0 INTRODUCTION

2.1 Background

B.C. Hydro propose to construct and operate a run of the river hydroelectric dam on the Columbia River approximately 3 km upstream of the City of Trail at Murphy Creek. The tentative project consists of a 28 m high earth-rockfill dam with five 60 MW turbine generators.

Phase II environmental investigations on water quality in the lower Columbia basin undertaken by the B.C. Ministry of Environment identified a number of impacts of the proposed project on water quality. [1] Their study concluded that the Murphy Creek Dam would not significantly alter the flow pattern in the Columbia, but it would raise water levels upstream of the dam and reduce flow velocities and effluent dispersion rates and increase residence time in the impoundment. In addition, the report identified several water quality impacts not related to B.C. Hydro from BC Timber Ltd. (formerly Canadian Cellulose Co. Ltd.) mill discharges including sublethal stress on aquatic life, colour, taste and odour.

Furthermore, BC Timber Ltd. which is owned by British Columbia Resources Investment Corporation has indicated investigations are underway to increase production. The company is considering broadening its range of products and it is considering paperboard, corrugated media and unbleached kraft. BC Timber Ltd. represents the largest source of waste discharge in the study region.

As a result of the concerns identified by the B.C. Ministry of Environment and the proposed expansion plans at BC Timber Ltd., B.C. Hydro retained IEC International Environmental Consultants Ltd. to conduct an assessment of Columbia River water quality impacts from the proposed development.

2.2 Study Objectives

The objectives of the water quality study were:

1. to provide an inventory of water quality that could be impacted by the potential project within the study area;

2. to provide a qualitative and quantitative evaluation of impacts resulting from the potential project;

3. to provide an evaluation of water quality losses and gains in monetary terms for inclusion in a benefit costs analysis; and

4. to provide data for preparation of an environmental statement.

In order to achieve the objectives, B.C. Hydro retained IEC to conduct the necessary water quality study. IEC's work was undertaken in two phases.

Phase I - Inventory

This phase consisted of performing field investigations and office studies to assemble an inventory of data on existing conditions for the Columbia and Kootenay rivers within the study area on aspects of water quality including BOD, suspended and settleable solids, toxicity, colour, taste and odour, pH, temperature, dissolved gases and possible eutrophication.

This phase included evaluation of existing water quality data in the Columbia River at the Hugh Keenleyside Dam and downstream at the proposed Murphy Creek Dam site and in the Kootenay River at the Brilliant Dam. Sources and quality of industrial and municipal effluents and agricultural runoff were also evaluated.

Phase II - Effect of Proposed Project

The second phase consisted of assessing the effect of impoundment on the present sources of pollution in the Columbia and Kootenay rivers within the study area and predicting water quality in the new reservoir. The effect of impoundment and altered river flows on downstream river quality was assessed and mitigation measures were recommended.

The following sections of this report describe the proposed undertaking, present the existing environmental setting and predict impacts of the proposed project on water quality.

This report was prepared for B.C. Hydro in accordance with Terms of Reference for Environmental Studies for the Proposed Murphy Creek Project, Draft No. 2, February 1980 issued by the System Engineering Division (Appendix 4). Concurrent environmental assessment studies have been prepared by other contractors on other components of the environment such as wildlife, fish and aquatic habitats, climate, recreation and tourism, etc.

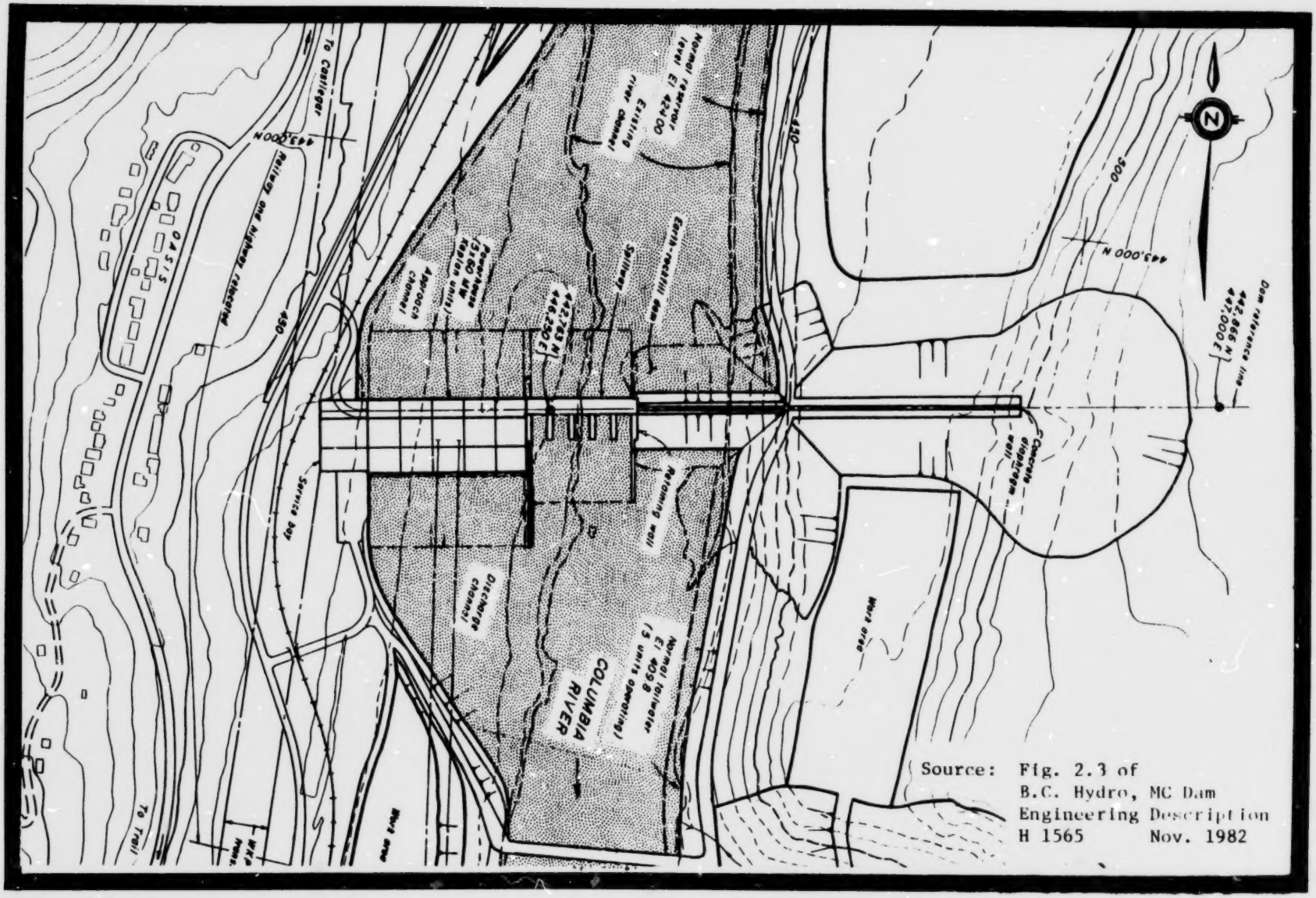
3.0 PROJECT DESCRIPTION

The proposed Murphy Creek Dam would be built on the Columbia River approximately 3 km upstream of the City of Trail and 23 km downstream of the confluence of the Columbia River and Kootenay River. Two dams, Brilliant on the Kootenay River and Hugh Keenleyside on the Columbia River are located immediately upstream of the proposed project. The Hugh Keenleyside Dam is the main regulator of flow in the lower Columbia River in Canada. The Murphy Creek project would provide no additional regulation of flow. B.C. Hydro is concurrently considering installation of 210 MW of generating capacity in the Hugh Keenleyside Dam. To maximize combined power production of Hugh Keenleyside Dam, Brilliant Dam and Murphy Creek Dam, an operating schedule known as Regime 2 has been proposed.

The headpond formed by the dam would have a total storage capacity of about an average day's inflow. The surface area of the headpond, at elevation 424 m, would be 1300 ha. B.C. Hydro assessed alternate levels based on bank stability and related safeline location, acquisition cost of private dwellings and/or protecting the shoreline, mitigation costs, municipal facilities affected by reservoir level and requirements of BC Timber Ltd., Castlegar mill. A 200-year flood return period was used for the design of flood protection. This report evaluating impacts on water quality deals primarily with the proposed 424 m maximum operating reservoir level.

The dam will utilize the latest technology in low head generating units. The installed capacity will be 300 MW at 424 m elevation. Figure 3.1 shows the general plan for the proposed Murphy Creek Dam.

The headpond receives water from 17 creeks and small streams; however, its major inputs originate from the Kootenay and Columbia rivers. Reservoir sedimentation studies were performed by B.C. Hydro [38] during the feasibility study. The Columbia River channel upstream from the proposed project and downstream from the Hugh Keenleyside Dam is composed primarily of gravelly, moderately coarse, and very coarse textured glaciofluvial and ice contact deposits. The small creeks deposit alluvial material to the main river during the freshet period. Loadings are generally low during non-freshet periods.



Proposed Murphy Creek Dam **Fig. 3.1**

B.C. Hydro (1981) has assumed that suspended sediments passing through the upstream reservoirs would continue on through the Murphy Creek headpond and all the sediments which might accumulate in the proposed reservoir would originate during floods from the 17 streams discharging to the reservoir. The expected time taken for sediment to occupy the dead storage volume and half of the live storage volume was calculated to be in excesss of 3,000 years.

Further studies by B.C. Hydro (1981) concluded that the probability of ice-formation on the Columbia River between Castlegar and Birchbank would decrease after the construction of the dam. Since ice formation was rare prior to 1968, occuring only once during the 70-year period of record, it was concluded that ice-formation on the headpond would not be an important consideration in project design.

Design

The proposed project will be designed to pass the following floods:

Diversion Flood	6,310 m^3/s
Spillway Design Flood	7,590 m^3/s
Probable Maximum Flood	13,100 m^3/s

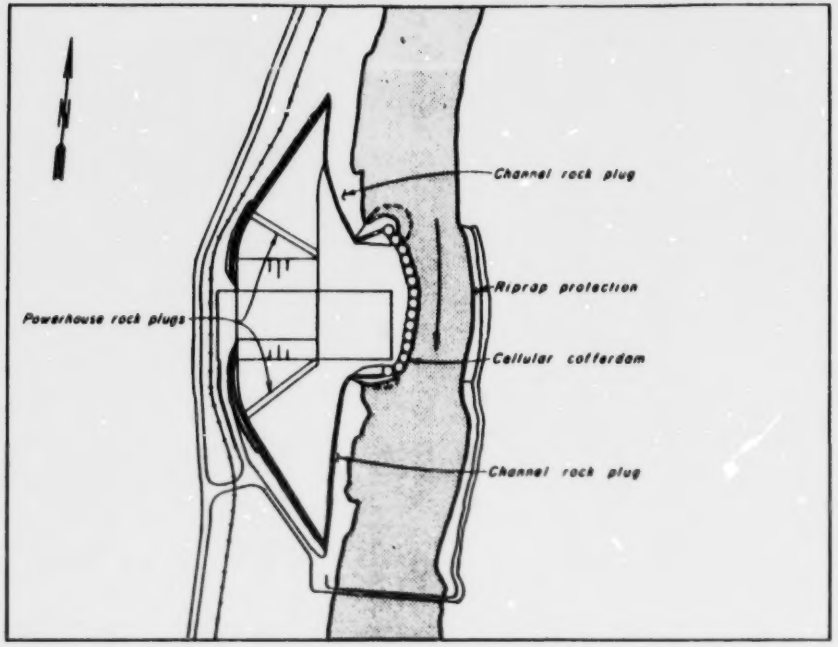
The spillway design will be an ogee crest with multiple bays. Control will be provided by radial gates. The spillway will be designed to pass the spillway design flood without surcharging the headpond at Castlegar. During this flood some of the flow will pass through the powerhouse.

A diversion of the Columbia River will take place in two stages during construction. [43] These stages are pictorially summarized in Figure 3.2. Stage I Diversion (Phase B) incorporates the following tasks:

i) widen river channel and place left bank riprap protection;
ii) construct cellular cofferdam;
iii) excavate spillway and powerhouse; and

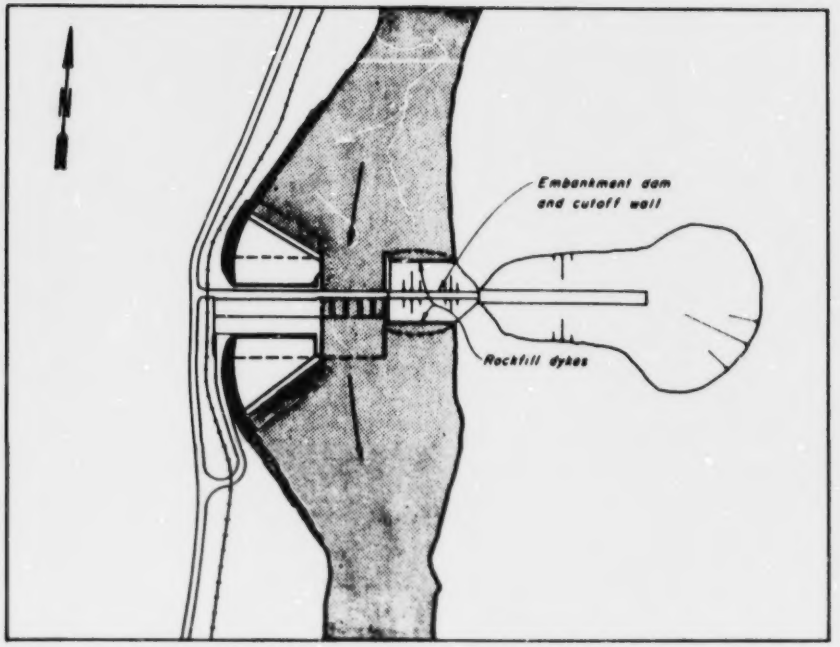
Murphy Creek Project – Columbia River Diversion Plans

Fig. 3.2



PHASE B (FIRST STAGE DIVERSION)

-WIDEN RIVER CHANNEL AND PLACE LEFT BANK RIPRAP PROTECTION
-CONSTRUCT CELLULAR COFFERDAM
-EXCAVATE SPILLWAY AND POWERHOUSE
-COMPLETE CHANNEL EXCAVATION EXCEPT FOR CHANNEL AND POWERHOUSE ROCK PLUGS



PHASE D (SECOND STAGE DIVERSION)

-REMOVE CELLULAR COFFERDAM AND CHANNEL ROCK PLUGS
-DIVERT RIVER
-CONSTRUCT THROUGH SPILLWAY ROCKFILL DYKES AND PLACE GRANULAR FILL
-COMPLETE CUTOFF WALL
-COMPLETE EMBANKMENT DAM CONSTRUCTION
-COMPLETE POWERHOUSE
-REMOVE TEMPORARY BRIDGE

Source: Fig. 6.2 of
B.C.Hydro, MCDam
Engineering Description
H 1565 Nov. 1982

iv) complete channel excavation except for channel and powerhouse rock plugs.

Stage 2 Diversion (Phase D) consists of the following:

i) remove cellular cofferdam and channel rock plugs;
ii) divert river
iii) construct through spillway rockfill dykes and place granular fill;
iv) complete cutoff wall;
v) complete embankment dam construction; and
vi) complete powerhouse.

Stage 1 Diversion part (ii); Stage 2, part (iii); and Phase E (removal of powerhouse rock plug cofferdams) are expected to adversely affect suspended solids concentrations in river water during construction. Construction materials would be obtained from: the left bank of the river close to the axis of the structures; excavation of the powerhouse spillway diaphram wall; and from Murphy Creek approximately 4 km from its confluence with the Columbia River. Spoil areas would include the right upstream bank and the Billy Creek watershed. Channel excavation is expected to last for over four years and is expected to be a likely source of suspended material.

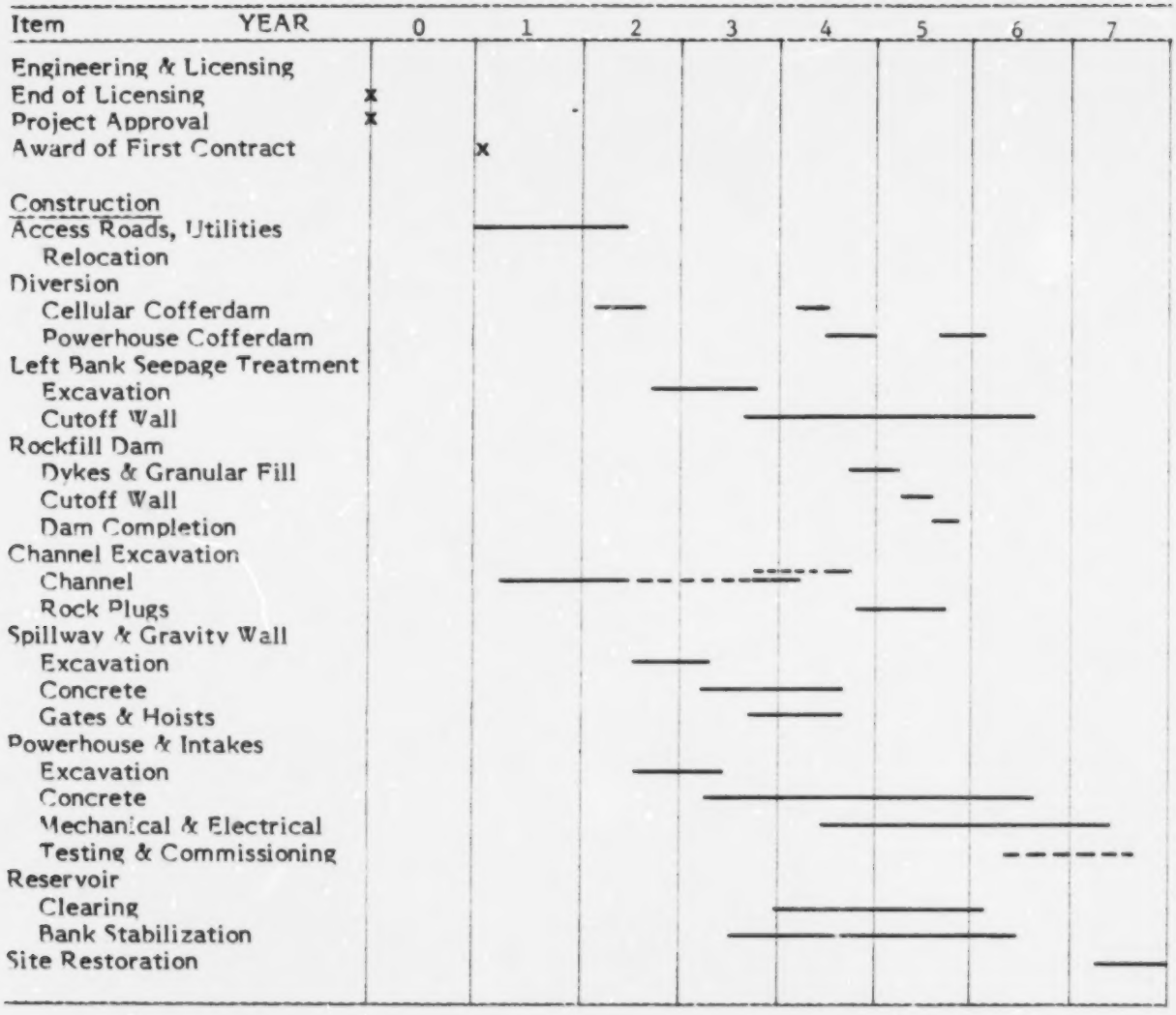
A five-bay spillway and five-unit powerhouse would be constructed. The dam will be rockfill extending 150 metres across the river and up to 28 metres high. The dam will have an impervious central core and outer compacted rockfill shell zones. A concrete gravity retaining wall will form the abutment for the west end of the dam.

The powerhouse would have five generators connected to five three-phase generator transformers. One overhead 230 KV transmission line would convey the power to the Selkirk substation.

The proposed construction would span 6 3/4 years (see Figure 3.3).

FIGURE 3.3

MURPHY CREEK PROJECT - CONSTRUCTION SCHEDULE



Source: Figure 6-1
B.C.Hydro MC Dam Description
H 1565 November, 1982

4.0 ENVIRONMENTAL SETTING

4.1 Inventory of Water Use

Within the study zone, the major municipal water user is the City of Castlegar, while the major industrial user is the BC Timber Ltd. pulp mill. The City and BC Timber Ltd. have a joint intake upstream of the Hugh Keenleyside Dam.

The water is screened at the intake, and the town pre-chlorinates its portion of water before distribution. Municipal water usage averages 0.4 to 0.5 m^3 per capita per day equivalent to 2800 to 3500 m^3/day. During summer months irrigation demand increases the use to approximately 3 m^3 per capita per day. Sewage flows to the two waste treatment systems do not vary significantly averaging 0.2 m^3 per capita per day equivalent to 1400 m^3/day. Projections predict an increase in population from the present 7,000 to 12,000 by 1990. The predicted future water use is estimated to be 4,800 to 6,000 m^3/day. This future use represents 0.004 to 0.006 percent of the 1979 average flow (1.5×10^8 m^3/day) in the Columbia River at Castlegar and will not affect flow in the river.

The BC Timber Ltd. mill uses as process water approximately 120,000 m^3/day or 218 m^3 per ton of production. An expansion of production from the present 550 metric tons per day to 1050 tons per day would result in a demand of 230,000 m^3/day assuming no additional water conservation practices are undertaken. With new technology total water demand in the expanded mill could be maintained at the present level. This consumption represents about 0.1 percent of the 1979 average flow in the Columbia and 1.0% of the minimum flow and would not affect flow patterns in the river.

The estimated peak day domestic water consumption for Castlegar in 1978 are shown below:

	1978 Population	Demand (m^3/d)
Castlegar North	3300	9090
Castlegar South	3100	9770
Total	6400	18,860

The projected peak day water consumption for Castlegar for a design population of 9,600 plus industrial development are shown below.

	Peak Day Water Demand (m^3/d) Minimum	Maximum
Castlegar North	2730	2950
Castlegar South	10,680	12,500
Sub-Total (New Development)	13,410	15,450
Existing Development (North & South)	18,860	18,860
TOTAL FOR CITY	32,270	34,310

The water supply would need to deliver about 38,600 m^3/d to provide for the long term population growth of 11,000 people.

The City of Trail obtains water from wells and from an intake on the Columbia River about 2 km downstream of the proposed Murphy Creek Dam.

There are numerous wells in the study area and groundwater studies by Pacific Hydrology Consultants showed that almost all groundwater originates as precipitation. (44) Groundwater along the Columbia River does not originate from the river but is derived from aquifers moving from uplands towards the river. There is a moraine

ridge in the vicinity of Selkirk College, the gravelly parts of which are an excellent aquifer. The District of Ootischenia uses two small perched aquifers in the Selkirk area for domestic and limited irrigation use. A proposed expansion of the District's water supply has identified the flats as the preferred location for new water wells. (39)

It is noted that this proposed water project is considering drawing water from the flats, an area which would be partially submerged upon completion of the Murphy Creek project although the location of the proposed wells would be above the maximum probable flood water line.

4.2 Chemical Characteristics

The data base on water quality characteristics of the study area was obtained from the B.C. Ministry of Environment. (2) Data were available for a number of river sampling stations in the study area including:

- the Columbia River 0.5 to 1 km downstream from the Hugh Keenleyside Dam;
- the Kootenay River downstream from the Brilliant Dam; and
- the Columbia River at Birchbank, approximately 2.5 km upstream from Murphy Creek.

Additional data on effluent quality were also obtained from the B.C. Ministry of Environment for:

- the BC Timber Ltd. mill;
- the municipal waste stabilization pond of the City of Castlegar;
- the activated sludge plant of the City of Castlegar; and
- Selkirk College Treatment Plant.

Appendix 1 contains a detailed compilation of the water quality data for the Columbia and Kootenay rivers in the study area. In addition, Appendix 1 contains effluent data from the main point sources discharging to the study area. These data were obtained

from the B.C. Ministry of Environment Waste Management Branch and form the basis for the water quality discussions which follow.

Detailed analytical results and calculated averages were established from the data base for a wide range of physical and chemical parameters. For most of the parameters, averages were calculated from a minimum of 30 values. In addition, further water quality data were obtained for the Columbia River at BC Timber Ltd. and for Arrow Lakes Reservoir in 1980 from two field surveys conducted by IEC. Data are presented in Appendices A 2.3 and A 2.4. The following subsections describe existing water quality in the study area under headings for each chemical parameter.

4.2.1 Nitrogen

The installation of the Murphy Creek Dam would reduce river velocities and raise levels in the reservoir, possibly increasing the potential for algae growth and subsequent eutrophication. As algae growth is often nitrogen or phosphorus limited, nitrogen and phosphorus species are examined in this and subsequent sections.

Average concentrations and daily loadings for total nitrogen, ammonia nitrogen (NH_3-N), total kjeldahl nitrogen (TKN) and nitrate/nitrite (NO_3/NO_2-N) at three locations along the river are presented in Table 4.1. The average daily loading was based on the average yearly flow for 1979. The loading for total nitrogen and each nitrogen species at the Birchbank sampling location was compared to the sum of the loadings at the upstream locations. A comparison of the upstream and downstream loadings suggest no appreciable source of nitrogen within the study area. Nitrogen loadings from the only known major source, BC Timber Ltd., are compared in Table 4.2 with the average daily loadings at Birchbank. Examination of the tables reveals that the contribution of this point source to the upstream nitrogen load is insignificant although the BC Timber Ltd. loading is approximately 30% of the net increase calculated at Birchbank. A variance of only 5% in the concentration and flow data would produce a variance of $\pm$ 1500 kg/day in total nitrogen, more than the difference calculated at Birchbank.

TABLE 4.1

EXISTING NITROGENOUS CONCENTRATIONS AND LOADINGS[1]

	Columbia River just below Hugh Keenleyside Dam		Kootenay River just below Brilliant Dam		Columbia River at Birchbank			
	Avg. Conc. (mg/L)	Avg. Daily Loadings (kg/d)	Avg. Conc. (mg/L)	Avg. Daily Loading	Avg. Conc. (mg/L)	Avg. Daily Loadings (kg/d)	% of Upstream Loadings	Net Change (kg/day)
NH_3-N	0.009	970	0.007	365	0.009	1,440	108	+105
NO_2/NO_3-N	0.124	13,390	0.055	2,850	0.089	14,225	88	-2,015
organic N	0.059	6,375	0.098	5,080	0.09	14,385	126	+2,930
TKN	0.068	7,345	0.105	5,445	0.099	15,825	124	+3,035
Total N	0.192	20,735	0.16	8,295	0.188	30,050	104	+1,020

[1] Data from B.C. Ministry of Environment (1976 - 1979)

[2] TKN = Total Kjehdahl Nitrogen = NH_3 + organic nitrogen; Total N = TKN + NO_2/NO_3 - N

TABLE 4.2
EXISTING NITROGENOUS CONCENTRATIONS AND LOADINGS[1]

	BC Timber Ltd. Discharge		Columbia at Birchbank
	Concentration (mg/L)	Avg. Daily Loadings (kg/day)	Avg. Daily Loadings (kg/day)
NH_3-N	0.77	70	1,440
NO_2/NO_3-N	0.435	50	14,225
Organic N	1.49	180	14,385
TKN[2]	2.26	270	15,825
Total N[2]	2.695	320	30,050

[1] Data from B.C. Ministry of Environment (1976 - 1979)

[2] TKN = Total Kjehdahl Nitrogen = NH_3 + organic N; Total N = TKN + NO_2/NO_3 - N

Concentrations for the various nitrogen species can be compared to Federal water quality guidelines. The Environment Canada water quality guideline for un-ionized ammonia is 0.02 mg/L for the protection of freshwater aquatic life. [3] At Birchbank, assuming a temperature of 20°C and a pH of 8.0, a total ammonia concentration of 0.011 mg/L (0.009 mg/L of NH_3-N) would give an un-ionized concentration of 0.0004 mg/L. This concentration is below the 0.02 mg/L un-ionized ammonia criterion and while the total ammonia concentration is below the B.C. drinking water quality objective of 0.5 mg/L. [4] Throughout this evaluation Federal water quality guidelines have been referenced wherever B.C. objectives are unavailable.

Drinking water quality objectives in B.C. for nitrate (NO_3) and nitrite (NO_2) nitrogen are 10 mg/L. [4] The average concentration of these species as shown in the Table 4.1 are below these objectives. Health and Welfare Canada, in guidelines for drinking water quality, recommend a maximum acceptable concentration for nitrate plus nitrite nitrogen of 10.0 mg/L and 1.0 mg/L for nitrite nitrogen [5] The concentrations of these species are also below the Health and Welfare guidelines. It is concluded that excessive nitrogen concentrations and possible eutrophication in the Columbia River in the reach from the Hugh Keenleyside Dam to Birchbank are not of concern under the existing conditions.

4.2.2 Phosphorus

Average concentrations and daily loadings for phosphorus are presented in Tables 4.3 and 4.4. Examination of the tables reveals that the major point source, BC Timber Ltd. represents approximately 7% of the phosphorus loadings to the study area.

The significance of these phosphorus loadings can be evaluated through a comparison with the concentration which may cause excessive plant growth in rivers and streams. Federal water quality guidelines limit the total phosphorus concentration to 100 ug/L (0.10 mg/L) for flowing water. [3] The average concentration of total phosphorus at Birchbank was 10 ug/L or one-tenth of the Federal guideline.

TABLE 4.3

PHOSPHORUS SPECIES CONCENTRATIONS AND LOADINGS[1]

	A		B		C			
	Columbia River at Hugh Keenleyside Dam		Kootenay River at Brilliant Dam		Columbia River at Birchbank			
	Avg. Conc. (mg/L as P)	Avg. Daily Loading (kg/day as P)	Avg. Conc. (mg/L as P)	Avg. Daily Loading (kg/day as P)	Avg. Conc. (mg/L as P)	Avg. Daily Loadings (kg/day as P)	C as % of A & B Loading	Net Change (kg/day as P)
Orthophos-phate	0.003	324	0.0058	301	0.0044	703	112	78
Total Phosphorus	0.0067	724	0.013	674	0.010	1,598	114	200

[1] Data from B.C. Ministry of Environment (1976 - 1979).

TABLE 4.4

PHOSPHORUS CONCENTRATIONS AND LOADINGS[1]

	A		B	C	
	BC Timber Ltd. Discharge		Brilliant Plus Hugh Keenleyside	Birchbank	
	Concentration (mg/L as P)	Avg. Daily (kg/day as P)	Avg. Daily (kg/day as P)	Avg. Daily kg/day as P)	C as % of A & B Loading
Orthosphosphate	0.7	84	625	703	99
Total Phosphorus	0.92	111	1,398	1,598	106

[1] Data from B.C. Ministry of Environment (1976 - 1979)

Again, it is concluded that under existing conditions, possible eutrophication from phosphorus concentration is not a concern in the reach of river from the Hugh Keenleyside Dam to Birchbank.

4.2.3 Dissolved Gases

Total dissolved gas levels were investigated in the Columbia River by the B.C. Ministry of Environment. [1] They found dissolved gases to be consistently above 110 percent of saturation downstream from the Hugh Keenlyside Dam. Total dissolved gas levels up to 144 percent saturation were recorded between the dam and the confluence with the Kootenay River. Downstream from the Kootenay River, values decreased to a maximum of 136 percent saturation due to the inflow of Kootenay River water containing lower maximum dissolved gas levels of 132 percent saturation. Further reductions were caused by equilibration. High levels of dissolved gas supersaturation in the river could cause gas bubble disease in fish, [1] although few adverse effects have been noted in fish caught during periods of critically high levels.

4.2.4 Dissolved Oxygen

Dissolved oxygen levels and saturation percentages from the data base are summarized in Table 4.5. Based on the twenty-five water samples collected from 1976-1979, the data showed the percent saturation of oxygen below the Hugh Keenleyside Dam varied from 82 to 122 percent with an average near 100 percent. The average percent saturation at Birchbank of 98 percent indicates that significant deoxygenation does not occur through the length of the study area. An examination of the data revealed that supersaturation (values greater than 100 percent) occurred mainly during the summer and fall months as concluded by the B.C. Ministry of Environment study. [1] These measurements of dissolved oxygen saturation support the conclusions of B.C. Ministry of Environment for total dissolved gases.

To evaluate changes in Dissolved oxygen (DO) saturation through the length of study reach, data were selected where concurrent measurements had been made downstream of Hugh Keenleyside on the Columbia River, downstream of Brilliant Dam on the

TABLE 4.5

SUMMARY OF DISSOLVED OXYGEN LEVELS IN STUDY AREA[1]

River and Location	Average Dissolved Oxygen (mg/L)	Percent Saturation			Number of Values Examined
		Average	Maximum	Minimum	
Columbia at Hugh Keenleyside Dam	11.34	97	122	82	25
Kootenay at Brilliant Dam	11.58	100	120	87	25
Columbia at Birchbank	11.59	98	114	83	25

[1] Data from B.C. Ministry of Environment (1976 - 1979)

Kootenay River and at Birchbank on the Columbia River. Based upon the measurement of the dissolved oxygen at Hugh Keenleyside and Brilliant Dam, the corresponding values were calculated for the combined flow at the confluence of the Kootenay and Columbia rivers. These calculated values are presented in Table 4.6 together with corresponding measured values at Birchbank.

The annual mean dissolved oxygen concentration did not change in the reach of river from the confluence to Birchbank, a distance of approximately 23 km. Only minor variations of individual measurements were indicated.

In general, existing dissolved oxygen concentrations in the study area were high and they did not show any appreciable sag in the reach from BC Timber Ltd. to Birchbank.

4.2.5 Turbidity, Suspended Solids and Colour

Turbidity, suspended solids and colour data from 1974 to 1979 are summarized below.

		Kootenay River	Columbia River		
		below Brilliant Dam	below Hugh Keenleyside Dam	Castlegar	Birchbank
Turbidity (J.T.U.)	range	0.2 - 1.5	0.4 - 4.0	0.2 - 2.1	0.4 - 9.0
	average	0.7	0.9	0.8	0.98
S.S. (mg/L)	range	1 - 10	1 - 28	1 - 4	1 - 11
	average	3.5	3.9	1.7	2.3
Colour (T.A.C.)	range	1 - 15	1 - 7	1 - 19	1 - 11
	average	3.6	2.4	4.7	3.6

TABLE 4.6
DISSOLVED OXYGEN AT CONFLUENCE OF COLUMBIA AND KOOTENAY RIVERS AND AT BIRCHBANK

	CALCULATED Confluence of Columbia and Kootenay Rivers (assuming complete mixing)			MEASURED Columbia River at Birchbank		
Flow[1] m^3/sec	Dissolved Oxygen mg/L	Temperature ^oC	Percent Saturation %	Dissolved Oxygen mg/L	Temperature ^oC	Percent Saturation %
1250	10.25	12	95	10.1	11.5	92
1740	10.71	11.8	99	11.5	10	102
1390	12.6	5	98	12.3	5	96
1430	12.33	7.8	103	12	6.2	96
1920	11.39	11.9	105	11.2	8.8	96
2530	10.03	15	98	11	14.5	107
4190	10.81	13.6	103	11	14.7	107
1500	13.46	4.8	105	12	4	91
2040	14.13	3.5	106	14	3.5	105
1760	14.85	4.2	113	15	4.5	115
2120	14.33	5.9	114	14.8	6	118
1590	12.45	3.2	93	13	3.5	97
1830	12.13	6.1	97	11.6	6.6	94
Mean	12.27			Mean 12.27		

1. as measured at Birchbank.

The data show that both the Columbia and Kootenay rivers above and below their confluence contain low levels of suspended matter and turbidity typical of mountain drainage basins. In addition, upstream suspended solids probably settle in the head ponds of the Brilliant and Hugh Keenleyside dams.

Although BC Timber Ltd. represented the largest point source of suspended solids discharge to the study area, the river water quality did not reflect this source.

Average colour values in the Columbia River showed a small increase between the Hugh Keenleyside Dam and Castlegar, attributed to effluent discharge from BC Timber Ltd. Although this increase is not significant, higher colour values were related to low river flows. (1) Drinking water objectives for treated water are 5 true colour units with a maximum acceptable value of 15. At extreme low flows, colour levels persistently greater than 15 could impair downstream drinking water uses.

4.2.6 Trace Metals and Compounds

Analyses of trace metals and compounds of water samples from the study area have been compiled by B.C. Ministry of Environment. (2) Table 4.7 summarizes these data for the period 1973 to 1979 and compares the results with water quality guidelines of Environment Canada. The tabulated values are averages from 8 to 46 analyses at each station.

The results indicate that trace compound concentrations are low in this section of the Columbia River with the exception of cadmium, cyanide and phenol. Although cadmium and cyanide concentrations exceed surface water quality objectives the concentrations are below the Federal drinking water recommended maximum acceptable values of 5 ug/L and 200 ug/L respectively. Phenol values also exceed the recommended maximum value for drinking water of 2 ug/L.

4.2.7 Foam

Foam has been observed in the river on at least two occasions, one at low flow (146 m^3/sec) and at relatively high flow (1500 m^3/sec). Foaming can be considered an aesthetic problem for short periods at low river flow situations. (1)

TABLE 4.7
AVERAGE VALUES OF TRACE METALS AND COMPOUNDS IN COLUMBIA AND KOOTENAY RIVERS

	Hugh Keenleyside Dam ug/L	Brilliant Dam ug/L	Birchbank ug/L	Federal Water Quality Guidelines: Protection of Aquatic Life ug/L	Federal Water Quality Guidelines: Drinking Water ug/L
Arsenic (diss.)	5.7	5.1	5.0	10.0	50.0
Cadmium (total)	0.5	0.5	0.52	0.2	5.0
Copper (total)	1.8	1.2	1.1	5.0	1.0
Iron (total)	170.0	120.0	110.0	300.0	50.0
Lead (total)	1.3	1.3	1.1	30.0	50.0
Mercury (total)	0.05	0.05	0.05	0.2	1.0
Zinc (total)	6.4	5.8	12.0	30.0	5000.0
Cyanide	10.0	-	10.0	5.0	200.0
Phenol	2.4	2.0	2.8	1.0	1.0

4.2.8 Taste and Odour

The influence of the BC Timber Ltd. effluent on taste and odour of Columbia River water has been reported by B.C. Ministry of Environment. [1] They report that taste problems would occur frequently upon chlorination at Castlegar if Columbia River water were used for domestic purposes without additional treatment. An odour panel detected odour in river water containing effluent at a 1:8200 dilution giving a Threshold Odour Number (T.O.N.) of 8200. Since the acceptable T.O.N. for treated drinking water is four, at no time would existing flow in the Columbia River provide adequate dilution.

4.2.9 Fish Flavour Impairment

B.C. Ministry of Environment also reported on fish flavour impairment (tainting) by effluent from the pulp mill. [1] Results of the tests indicated that fish flavour was impaired, but it was not definitely associated with the pulp mill effluent as both control and experimental fish were affected. The tests were performed in fish caught during relatively average flows. It was assumed that more conclusive results could be obtained at low river flows.

4.2.10 Toxicity

Data from the data base (Appendix 1) indicate that the BC Timber Ltd. effluent was toxic (96-hr LC_{50}) at effluent concentrations ranging from 8 to 63 percent. Sublethal stresses on fish can be avoided at concentrations below 0.05 of the 96-hr LC_{50}. At eight percent effluent the sublethal stress concentration would be 0.4 percent. For this case, at an effluent flow of 1.4 m^3/sec, required total dilution flow in the Columbia River would be 350 m^3/sec. Existing river flows of 350 m^3/sec or less could occur for only 9 percent of the time. [1] At these low flows the pulp mill effluent possibly could induce sublethal toxic effects on fish.

4.3 Thermal Stratification

4.3.1 General

The phenomenon of thermal stratification in lakes and deep reservoirs occurs when layers of water of differing density resist the mixing effect caused by surface wind forces. Since installation of the Murphy Creek Dam would cause river velocities to decrease and depth to increase, a potential for thermal stratification exists. The following section contains a general discussion of heat balances in water bodies.

In spring, surface waters are warmed by incident solar radiation resulting in ice melt. As the water reaches a temperature of 4°C, the maximum density is reached and convection currents are set up as the dense water sinks. These currents, aided by wind, serve to mix the water until the lake is at a uniform temperature and density. This spring mixing process is termed the spring overturn or spring circulation period. During the summer, the longer days result in longer periods of solar radiation and the winds are usually calmer. The surface waters warm rapidly, becoming lighter than the lower waters. Although the wind continues, its contribution to mixing is low as the thermal density gradient opposes the wind force. As the summer progresses, the resistance to mixing becomes greater than the wind forces. At that time the surface waters are much warmer than the colder underlying waters and thermal stratification exists.

The uppermost region of warm water is termed the epilimnion. The zone of rapid drop in temperature with depth is the thermocline. The metalimnion describes a layer of water that includes a gradient on either side of the thermocline. The zone below the metalimnion is designated the hypolimnion.

In autumn, the solar radiation decreases, the surface waters lose heat and the thermal resistance to mixing also decreases. Wind generated currents reach deeper into the lake and the metalimnion disappears until the lake is again at a uniform temperature and density. This period of autumnal circulation is called the fall overturn.

4.3.2 Arrow Lakes Reservoir

To determine the potential for stratification in the Murphy Creek reservoir, the behaviour of a well stratified lake in the immediate vicinity was examined. Arrow Lakes Reservoir upstream from the Hugh Keenleyside Dam was chosen as temperature data were available for a number of years at 2 locations in the reservoir, near Galena and near Syringa. Arrow Lakes Reservoir is approximately 170 km long, average width is 2 km and depth averages 32 metres.

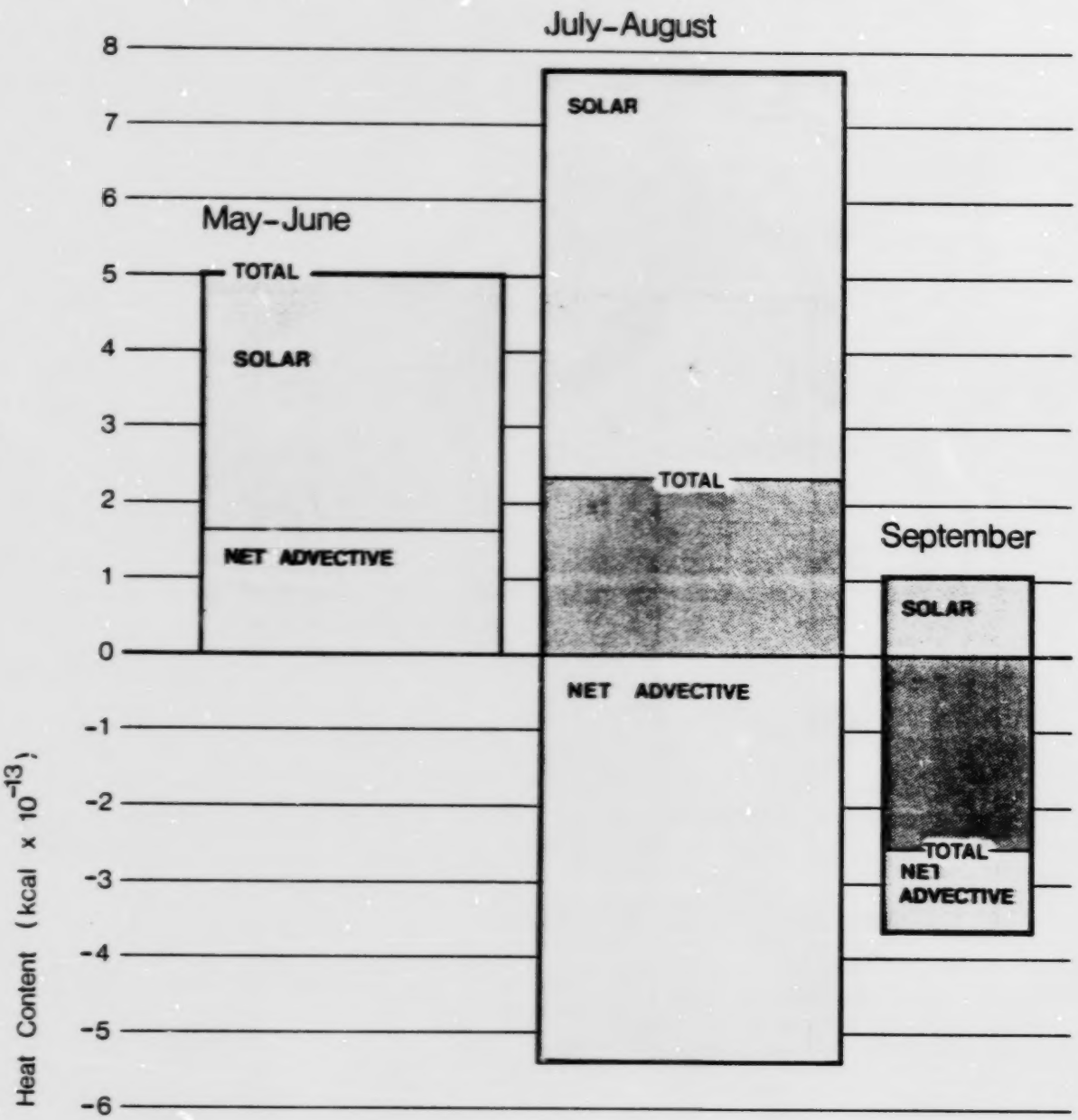
The heat content of the reservoir at Galena was assumed representative of the entire reservoir and was compared at successive time intervals with the advective heat flux of the Columbia river flow. Differences were considered to be a measure of net heat flux or bulk transport of heat. The calculated net heat flux would include the net advective heat flux from minor tributary flows and the net solar radiation. Advective heat flux from minor tributary flows could not be determined easily, however net heat flux could be calculated and was considered representative of net solar heat flux.

The heat content of the Arrow Lakes Reservoir was based on temperature depth profiles for June, August and September at Galena. The total heat content in a vertical component of unit surface area was determined and multiplied by the estimated total surface area to obtain the total heat content. The calculated heat content was then compared with the calculated advective flux. Any difference was taken as a measure of the net solar flux over the examined periods. The heat content and contribution from solar and net advective flux are given in Table 4.8 and illustrated in Figure 4.1. It was noted that during July-August, a net increase in heat content was observed due to a large positive solar contribution although a net advective heat loss occurred. The heat fluxes to the reservoir are compared in Table 4.9 and Figure 4.2. During July-August, the period of most extreme stratification, the solar input heat flux was similar to the advective input heat flux to the reservoir.

Values for the calculated net solar heat flux were then divided by the total surface area and the number of days in the period to produce a unit daily solar heat flux. The calculations and data used to establish solar heat flux are presented in Appendix 2.

Period Differences in Heat Content of Arrow Lakes Reservoir

4.1



Comparison of Advective & Solar Heat Fluxes To Arrow Lakes Reservoir

4.2

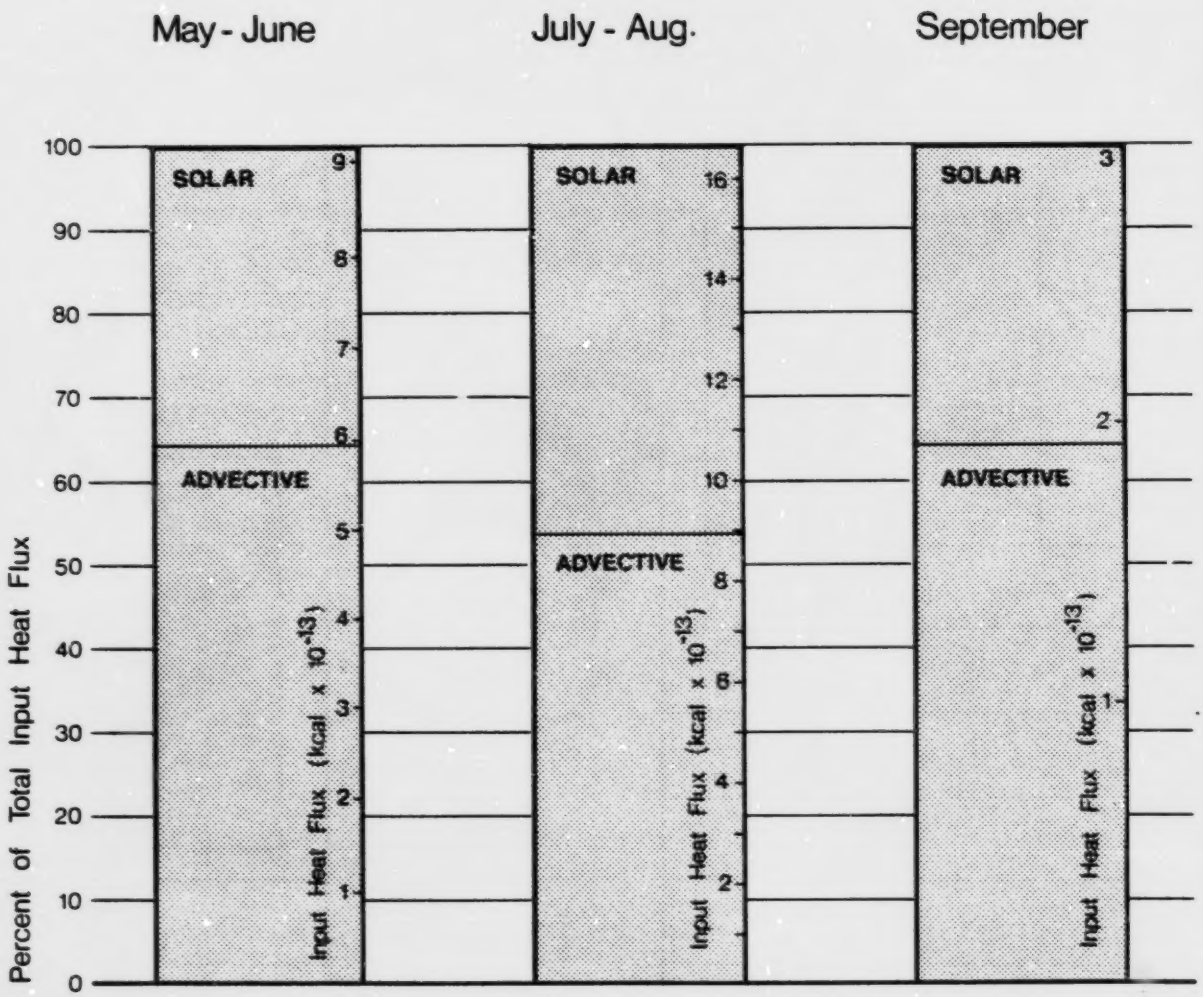


TABLE 4.8
ARROW LAKES RESERVOIR HEAT FLUX

	Heat Flux Increase From (kcal)	Net Advective Heat Flux (kcal)	Net Solar Heat Flux (kcal)
May - June	5.02×10^{13}	1.59×10^{13}	3.43×10^{13}
July - August	2.36×10^{13}	-5.36×10^{13}	7.72×10^{13}
September	-2.55×10^{13}	-3.66×10^{13}	1.11×10^{13}

Note: A negative value indicates a decrease in heat content or a heat loss from the lake.

TABLE 4.9
HEAT FLUX INPUTS TO ARROW LAKES RESERVOIR

	Advective Heat Flux		Solar Heat Flux	
	kcal	% of total in	kcal	% of total
May - June	5.93×10^{13}	64	3.43×10^{13}	36
July - August	8.91×10^{13}	54	7.72×10^{13}	46
September	1.93×10^{13}	64	1.11×10^{13}	36

The following unit daily solar heat fluxes were calculated:

May - June	1.65×10^3 kcal./m^2-day
July - August	3.72×10^3 kcal./m^2-day
September	1.09×10^3 kcal./m^2-day

These values were compared to data on solar radiation provided from publications and from discussions with staff of Environment Canada, Atmospheric Environment Services. [7] Mean daily net radiation data were available from a station at Summerland, in the Okanagan Valley, approximately 20 km north and 150 km west of Castlegar. Average values for the same time periods were:

May - June	$2.0^2 \times 10^3$ kcal./m^2-day
July - August	1.79×10^3 kcal./m^2-day
September	0.99×10^3 kcal./m^2-day

These measured values compared with the order of magnitude estimates calculated from the conditions of Arrow Lakes Reservoir. As such, IEC estimates that similar results would apply to the proposed Murphy Creek Reservoir.

4.4 Effluent Sources and Quality

4.4.1 General

Major point source effluent discharges in the study area include the BC Timber Ltd. mill, the City of Castlegar waste stabilization pond and activated sludge plant and the extended aeration plant of Selkirk College. The Castlegar treatment lagoon commenced operation in 1965 and Selkirk College introduced aerated treatment in 1966.

Tables A 1.6 to A 1.8 of Appendix 1 contain detailed results of effluent quality from the major sources in the study area. Table 4.10 which follows summarizes the discharges from each of the major point sources.

TABLE 4.10
EFFLUENT SOURCES AND AVERAGE QUALITY

	BOD		TSS		Total Nitrogen		Total Phosphorus		Flow	
	kg/D	%	kg/D	%	kg/D	%	kg/D	%	m^3/D	%
BC Timber Ltd.	23,140	99.82	16,885	99.7	320	92	111	94.1	119,730	98.9
Castlegar Waste Stabilization Pond	25	0.11	35	0.21	14	4	3	2.5	760	0.6
Castlegar Activated Sludge Plant	9	0.04	6	.04	12	3.5	3	2.5	450	0.4
Selkirk College	7	0.03	9	.05	2	.5	1	.9	170	0.1
TOTAL	23,181	100.	16,935	100.	348	100	118	100	121,110	100.

It is noted that the BC Timber Ltd. discharge represents almost 99 percent of the total flow, greater than 99 percent of the 5 day biochemical oxygen demand (BOD_5) and suspended solids loading, 92 percent of the nitrogen loading and 94 percent of the phosphorus loading. BC Timber Ltd. is the major effluent source to the river. When the flows of the various waste sources are compared to the 1979 average flow of the Columbia River at the Hugh Keenleyside Dam (approximately 454000 m^3 per day), the flows other than that from BC Timber Ltd. are minimal.

As the BC Timber Ltd. effluent is the largest point source discharge to the Columbia River, the behaviour of the effluent is discussed more fully below.

4.4.2 BC Timber Ltd.

The Columbia River between the mill and the City of Castlegar is a mixing zone for the effluent from the mill outfall diffuser. Effluent data from the BC Timber Ltd. mill are summarized in Table A 1.6 of Appendix 1. The mill effluent discharges through six circular diffuser ports located 12 m apart at the end of a 300 m submerged pipeline. The diffuser ports discharge horizontally 10 to 20 m below the present water surface. Approximately 1.4 m^3/sec of mill effluent is discharged at 28°C. Density differences cause the discharge plume to rise upward as it travels downstream. The effluent surfaces about 80 to 200 m downstream from the diffuser. Typical surface dilutions are 30 to 200 depending on river velocity, depth and temperatures. Once surfaced the plume diffuses to fill the width and depth of the channel completely mixing with the river flow.

Average BC Timber Ltd. effluent discharge characteristics for BOD, TSS, total nitrogen (N), total phosphorus (P) and flow, were presented in Table 4.10. Effluent quality of the BC Timber Ltd. mill are compared to the 1973 permit requirements in Table 4.11. It is to be noted that permit conditions for the mill are being reviewed and an expansion is proposed and more stringent limits for the mill discharge may be imposed.

The mill is proposing to expand production from 550 metric tons per day to approximately 1050 tons per day. A biological treatment system with a 5 day aerated

lagoon has been proposed for the expanded mill and consideration is being given to relocating the effluent diffuser discharge closer to the Hugh Keenleyside Dam. The treated effluent will probably be required to meet B.C. Ministry of Environment level A standards which are also given in Table 4.11.

BC Timber Ltd. Effluent Plume Monitoring

A survey was performed by IEC to establish BC Timber Ltd. effluent plume dispersion in the Columbia River. Field data are presented in Appendix 2, Table A 2.3. The survey of the plume was performed on 18 and 19 September, 1980 to measure the horizontal and vertical dimensions of the plume as it dispersed in the Columbia River. Five transects parallel to the river direction were measured starting above the BC Timber Ltd. discharge pipe and diffuser and ending 709 m downstream. Soundings were taken from a stationary boat by lowering the probes through the water column and recording depth, conductivity and temperature. Soundings were used to plot bottom contours. The data from the field survey are summarized in Table 4.12.

When lowering the probe through the water column the conductivity readings remained fairly constant to a depth and then changed rapidly. When the meter reading changed rapidly the depth was recorded and these recorded depths indicated the interface between the effluent plume and river water.

On the right bank (south side), the plume formed a back-eddy below the log boom. On the left bank the plume spread across the river and reached the left bank about 25 m downstream from the diffuser.

On 18 and 19 September, a reconnaissance dive was made in the Columbia River to determine, and mark with floats, the position of the BC Timber Ltd. effluent diffuser nozzles. As only five of the six nozzles could be located due to poor visibility, the anchors for flow measurement were placed 2 metres outside and 5 metres upstream of the five nozzles. Pictures were taken of each diffuser nozzle. On 19 September, measurement of water flow above the diffuser nozzles was performed by mooring the boat to the anchors and measuring the flow at ten points in the water column above the nozzles.

TABLE 4.11

BC TIMBER LTD. EFFLUENT CHARACTERISTICS, PERMIT REQUIREMENTS AND 1977 LEVEL A OBJECTIVES

Parameter	Existing Range	Existing Average	1973 Permit Levels	1977 Level A Objectives
Total suspended solids (kg/t)	2-297	29	15	10
BOD_5 (kg/t)	21-186	42	20	7.5
Temperature (^oC)	13.5-36	24	35	35
pH range	2-11.5	5.4	6.5-8.0	6.5-8.0
Dissolved Oxygen (after secondary treatment) (mg/L)	0-12.4	2	G 2.0	2.0
Toxicity (TLm at 96 hr) % effluent volume	8-62.5	22.7	90	100
Settleable solids (mL/L)	0-650	10	2.5	not listed
Mercaptans (mg/L)	0-29	1.7	L 2.0	not listed
Sulphides (mg/L)	0-38	1.4	L 1.0	not listed
Residual Chlorine (mg/L)	0-4.3	0.2	L 0.1	not listed

L = Less than

G = Greater than

TABLE 4.12

FIELD STUDY CONDITIONS - BC Timber Ltd.

Date	No. of Downstream Survey Transects	River Flow m^3/sec	River Temp. ^oC	River Depth m	Conductivity River umhos/cm	Conductivity Effluent umhos/cm
12/08/80	5	1,640	16.5	18	101	1,600
19/09/80	5	141	14.5	14	108	1,500

IEC collected water samples from the Columbia River above and below the BC Timber Ltd. mill to assist in establishing plume dispersion characteristics. Samples were collected 19, 20 September 1980 and returned to IEC's laboratory for analysis. Dissolved oxygen and temperature profiles were obtained insitu and secchi disc transparency was measured.

The two right hand diffuser nozzles were partially covered at their openings with cobble and gravel, however there was no flow interference. The left hand diffuser nozzle was covered to the lip by sand but again the flow was not restricted. The two remaining nozzles discharged well above the river sandy bottom.

The effluent from the left hand nozzle (north side) diffused downstream in a cone shape and merged with effluent from the other nozzles. Progressing from the left nozzle toward the right nozzle, the plumes moved outward and upward faster than downstream. At the right hand nozzle the plume looped back over itself in the back-eddy. From the right nozzle to the shore the water was turbid from the effluent which extended upward from the nozzle toward the bank.

4.4.3 Municipal Effluents

The Castlegar North wastewater treatment plant is located on the north side of the Columbia River on the old BC Timber Ltd. sawmill site, and consists of two aerated lagoons, a polishing cell and chlorination facilities. Discharge is by outfall to the Columbia River.

The original design of the lagoon system was based on a design population of 3500 peopie and an average daily wastewater load of 1500 m^3/D. The design capacity of the treatment system was recently increased to 2730 m^3/D and will handle an estimated population of 10,000 people.

The North treatment facility has sufficient capacity to provide for up to a tripling of the 1978 population level.

The Castlegar South wastewater treatment plant is located off Connors Road just north of both Highway 3A and CP Railway. The plant is an activated sludge facility that consists of an 24 m. diameter concrete tank fitted internally with partitions to form separate compartments. The plant has been designed to operate on the extended aeration principle until the population served exceeds about 4000 people, at which point conventional loading may be adopted. The system includes sludge holding lagoons.

The South plant was sized for an ultimate average daily design flow of 2300 m^3/D based on an assumed equivalent contributing population of 6000 people. This facility has capacity to provide for at least a doubling of the 1978 population.

Effluent data from the treatment plants for 1973-1979 are presented in Tables A 1.7 and A 1.8 in Appendix 1.

4.5 Agricultural and Recreational Uses

The Talisman Land Resource Consultants Ltd. (1980) report discussed land use in the study area. The historic role of agriculture and its present day salient features are described for the study area according to ten geographical areas. It was estimated that the study area contains 1,132 ha within the Agricultrual Land Reserve. Two-thirds of this land is classed as arable (within BCLI Classes 1-5) and almost half of this area can be termed prime agricultural (BCLI Classes 1-3) capable of supporting a diverse range of farming. At present only 2% of this agricultural land (approximately 20 ha) is under cultivation. An estimated 48% has been farmed but is now abandoned and the remaining 50% is uncultivated and is largely covered by shrubs and mixed wood forest.

Within the agricultural community, land use includes decadent orchards, forage land, grassland and hobby farming. These land uses do not place high demands on the soil. Modern agriculture methods including the use of chemical fertilizers and chemical control of crop pests is not practiced. This land is not heavily ranched. Stock pens and other intensive agricultural and horticultural techniques are not employed.

Water recreation in the study area is confined to sport fishing by some residents of the district, limited usage of beaches especially in the vicinity of Castlegar, and boating.

A comprehensive study of the impact of the Murphy Creek project on recreation tourism has been prepared by Edwin Reid and Associates (1981).

5.0 IMPACT ASSESSMENT

In this report data on the present condition of the river have been collected from existing sources and supplemented with field data collected by IEC on the river near the BC Timber Ltd. mill. The conceptual engineering plans of B.C. Hydro have been used for evaluation of environmental impacts on water quality. [9,12,42,43]

The impact of the hydroelectric project on the water quality in the Columbia River within the study area will be considered in two parts. These are a construction phase when the dam is being installed and an operational phase when the dam is used to generate electricity. The following sub-sections discuss the impacts of the project on water quality. The first sub-section contains a discussion of relevant water quality impacts associated with construction of reservoir structures based on a literature review.

5.1 Construction Impacts

5.1.1 Literature Review

A computer literature search was undertaken to assist in the determination of construction activities. The four data bases listed in Table 5.1 were searched using a combination of the following key words: dam(s), construction, river diversion. Approximately 7000 literature references relating to dams and dam construction were retrieved by the computer. These entries were then searched using the additional key word: water quality. A hundred report titles and/or abstracts were found. Following a manual evaluation, five reports were selected as containing pertinent information. [14,15,16,17,18] Other relevant studies were obtained through cross-referencing and telephone contacts. [19,20,21]

As expected, the literature revealed that the effects of dam construction depend on the type and size of the dam. The primary pollutant from dam construction was sediment and in-stream sources of suspended sediment included activities associated with;

TABLE 5.1
INFORMATION RETRIEVAL DATA BASES

Data Base	Information Category	Abstract Sources
NTIS	Multi-disciplinary	U.S. National Technical Information Service
Compendex	Civil, environmental and geological engineering	Engineering Index, Inc.
Energyline	Environmental impacts, resources, and electric power transmission	Environmental Information Centre, Inc.
Enviroline	Environmental studies	Environment Information Centre, Inc.

- cofferdam construction,
- stream channel dredging,
- earth moving and/or dumping,
- diversion structure construction and
- gravel washing runoff

Instream dam construction activities usually resulted in temporary and minor increases of downstream turbidity and suspended solids. [14,18,19]

A detailed study of the impacts due to the construction of the Libby Dam on the water quality of the United States reach of the Kootenai River was carried out by the U.S. Army Corps of Engineers, from 1967 to 1972. [21] They found the effects of dam construction on the river water quality were limited to elevated suspended sediment and turbidity values. The suspended solids increased on average, from 39 mg/L upstream of the dam site to 45 mg/L, downstream. It should be noted that higher suspended solids concentrations coincided with high run-off and the maximum daily value measured was 1,200 mg/L. In addition it is noted that the Murphy Creek Dam will be constructed in the dry so that similar peak concentrations are less likely at Murphy Creek. Significant short-term increases in suspended sediment and turbidity were associated with specific construction activities eg. channel diversions, cofferdam construction and settling pond drainage. The increase in suspended sediment from Libby Dam construction activities impacted on the aquatic insect community. Aquatic insect populations were suppressed up to 14.5 km downstream of the dam construction site. Extensive post operational monitoring by the U.S. Army Corps of Engineers has shown a tenfold increase in downstream fish populations resulting from the selective withdrawal to optimize temperatures (pers. comm.). Fishing activity downstream has increased from 60 days/km (preconstruction) to 400 days/km (post construction). A benthological survey was performed this year and will be published shortly. Preliminary results suggest an increase in diptera and return of caddisflies to the river. There has been a decrease in stonefly populations due to changes in gas supersaturation.

The remaining technical literature contained only general qualitative references to construction impacts. However, considerable data were available on operational impacts.

5.1.2 Murphy Creek Dam Construction

The Murphy Creek Dam is proposed as a zoned earth-rockfill dam about 150 m long and 28 m high.[44] Six and three quarter years of construction have been scheduled as depicted in Figure 3.3.

The following sub-sections review historic water quality data obtained during construction of the Hugh Keenleyside Dam and the Revelstoke Dam. These data were used to project potential impacts from construction of the Murphy Creek Dam with due consideration given to noted differences in construction techniques.

5.1.3 Hugh Keenleyside Dam Construction

Impacts attributed to the construction of the Hugh Keenleyside Dam were evaluated to assess possible impacts on Columbia River water quality from the construction of the Murphy Creek Dam.

Water quality and flow data were available for the periods prior to, and during the Hugh Keenleyside Dam Construction (see Appendix 3, Tables A 3.1 to A 3.12). Evaluation of these data indicated that turbidity and suspended solids increased during periods of construction. Suspended solids data were used to evaluate:

- background water quality and flow velocities prior to the construction of the Hugh Keenleyside Dam.
- changes in water quality and flow velocities due to dam construction activities, and
- changes in water quality with respect to recent background levels.

Preconstruction Conditions at Hugh Keenleyside Dam

Prior to the construction of the Hugh Keenleyside Dam, B.C. Hydro monitored levels of suspended solids in the Columbia River, from September 1963 to April 1965, at the old BC Timber Ltd. intake, Castlegar, Kinnaird and Pend'Oreille (Appendix 3 Tables A 3.1 to A 3.3). These data defined preconstruction river suspended solids concentrations and suspended solids loads were calculated from the data and are shown in Table 5.2. [22] The mean concentrations were calculated from discrete samples collected over an extended time frame. The upper 97.5 percentile concentration signifies that on the average, 2.5% of samples collected and analyzed would exceed this concentration.

There was a 1.3 mg/L difference between the average suspended solids concentration and the upper 97.5% percentile concentration (Table 5.2). The concentration data covered a wide range of flows from 1.81×10^7 m^3/day to 35.25×10^7 m^3/day, and the data showed only a weak correlation between the variation of the concentration of suspended solids with river flows. Since concentration was relatively independent of flow, the transported load of background suspended solids was highly dependent on flow. However, it is suspected that local precipitation events may produce increased turbidity. IEC's analysis was based on general conditions and perturbations caused by short term events could not be identified as the data base did not identify time of sample collection.

River velocities at and above the Hugh Keenleyside Dam site are shown in Table 5.3. [24] Peak velocities and peak flows occurred in the early summer, while low velocities and low flows occurred during the winter. High summer velocities of 0.30 m/sec. and 0.79 m/sec. would preclude deposition of silt. Normally, settlement would occur at velocities less than 0.12 m/sec. [24]

Conditions During Hugh Keenleyside Construction

B.C. Hydro monitored concentrations of suspended solids at stations located upstream and downstream of the Hugh Keenleyside Dam site, during construction from May

TABLE 5.2

KEENLEYSIDE DAM PRECONSTRUCTION LEVELS OF SUSPENDED SOLIDS: (1) SEPT. 1963 - APRIL 1965

CONCENTRATION		LOADING	
Mean (mg/L)	Upper 97.5th Percentile (mg/L)	Mean [2] (kg/day x 10^4)	Upper 97.5th Percentile (kg/day x 10^4)
1.2 $\pm$0.7	2.5	1.65 $\pm$0.6	56.9

1 Columbia River at Stn. 1 (Old BC Timber Ltd. Intake), Stn. 3 (Castlegar), Stn. 4 (Kinnaird), and Stn. 5 (Pend'Oreille)

2 Preconstruction loads calculated on basis of average monthly concentrations (Appendix 3, Tables A 3.1 - A 3.3) and average monthly flows (Appendix 3, Tables A 3.7 - A 3.9)

TABLE 5.3
COLUMBIA RIVER VELOCITIES (m/sec.)
KEENLEYSIDE DAM

Location	Data Category Time Period	Spring (Apr.-May)	Summer (June-Aug.)	Fall (Sept.-Oct.)	Winter (Nov.-Mar.)
Above Hugh Keenleyside Dam (686 m) Upstream	Background (1914-1962)	(0.05-0.46)	(0.30-0.79)	(0.12-0.55)	(0.05-0.31)
Above Hugh Keenleyside Dam (686 m) Upstream	Construction (Oct. 1965 - Mar. 1966)	-	-	(0.18-0.20)	(0.05-0.21)
At Hugh Keenleyside Dam[1]	Construction (Oct. 1965 - Mar. 1966)	-	-	(0.36-0.40)	(0.10-0.42)

1 Estimates based on assumption that velocities above Hugh Keenleyside Dam site were doubled at dam site due to closing of approximately half the river channel width by the coffer dam (27).

1965 to July 1967. [22] Construction activities included: dredging, coffer-dam construction, and earth dam construction. During construction of the dam, barge loads of material were discharged to the river. This included dumping of fill for the earth dam from April to July 1967 and dumping of sediment from channel excavation from February to May 1967 downstream of the dam. During the period of construction, B.C. Hydro undertook to provide East Trail and Kinnaird with a total of 1.9×10^4 m^3 per day drinking water from two wells as an alternate water supply. These wells were put on stream in the spring of 1965. In addition, B.C. Hydro installed modern water treatment plants at Tadanac and Warfield to assure potability and safety of Columbia River water supply during dredging activities at Hugh Keenleyside Dam site. [40] Monitoring at downstream stations, except Castlegar (Station 18) was discontinued before the summer of 1966. As most in-water construction occurred from May 1965 to December 1966, Castlegar (Station 18) data for this period were used to assess water quality impacts. [22,23]

Increased concentrations of suspended solids occurred at Castlegar during construction (Appendix 3 Tables A 3.3 to A 3.6) and as shown in Figure 5.1, the increases were independent of river flows. [22,25]

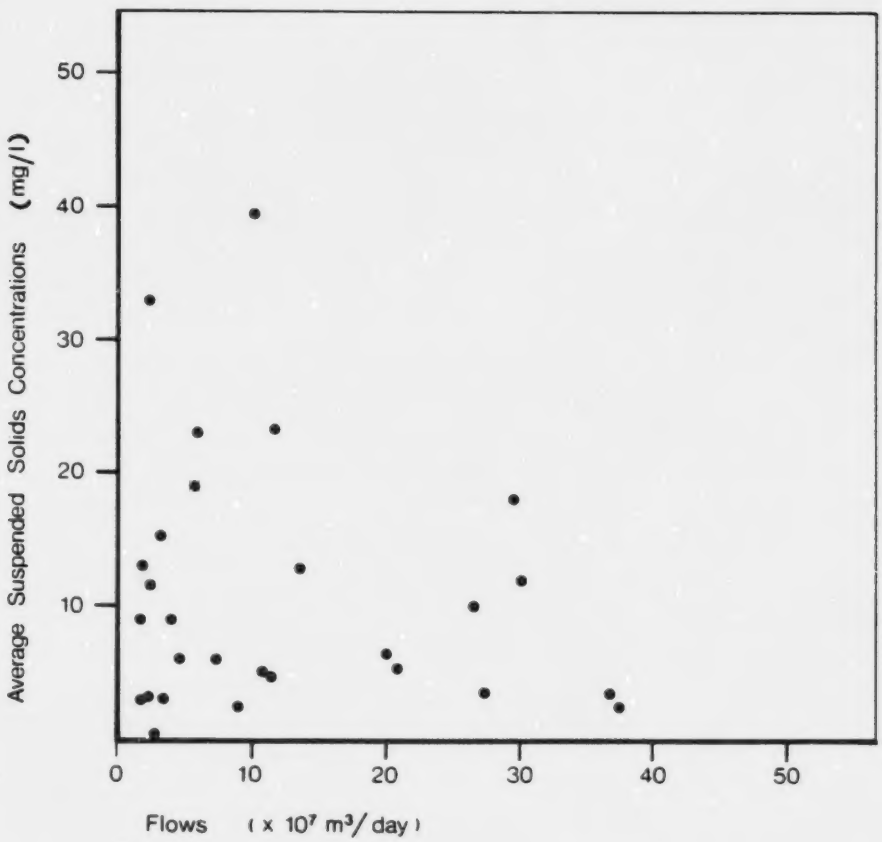
Suspended solids concentrations, river flows, and the various construction activities are presented in Figure 5.2. With the start of construction, suspended solids increased significantly above preconstruction levels. Construction of the coffer-dam caused the greatest increase in suspended solids. However, it was not possible to correlate specific construction activities with suspended solids.

Suspended solids concentrations measured at Castlegar during the Hugh Keenleyside Dam construction are summarized in Table 5.4. [22] Mean concentrations were calculated from daily suspended solids samples. The average increase in suspended solids attributed to dam construction was 11.5 mg/L, viz from 1.2 to 12.7 mg/L. Considerable variation in concentration was observed, as indicated by the upper 97.5/percentile limit of 32.0 mg/L. This variation reflected the effects of different construction activities on suspended solids concentration.

Concentration Suspended Solids vs Flow at Castlegar during Hugh Keenleyside Dam Construction

5.1

May 1965 – July 1967



Concentration Suspended Solids and Flows at Castlegar vs Activity Associated with Hugh Keenleyside Dam Construction

5.2

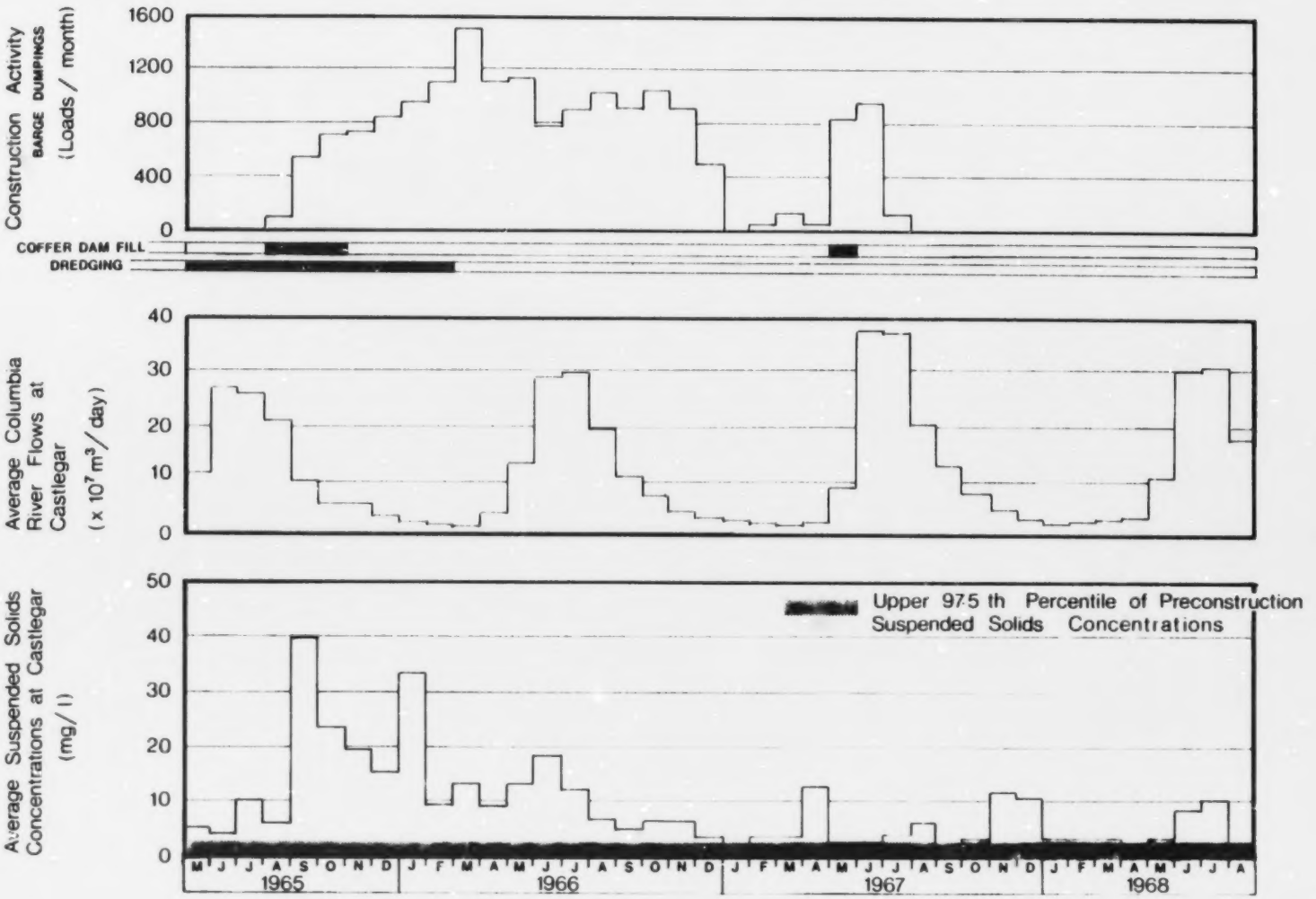


TABLE 5.4

SUSPENDED SOLIDS AT CASTLEGAR DURING HUGH KEENLEYSIDE DAM CONSTRUCTION: MAY 1965 - DECEMBER 1966

Mean Concentration (mg/L)	Upper 97.5 Percentile (mg/L)	Calculated Mean Increase due to Construction, (mg/L)
12.7 ± 9.8	32.0	11.5 ± 9.8

As only Station 1B, at Castlegar, was monitored during the construction period, regression analysis was used to estimate suspended solids concentrations at Kinnaird, Cominco and Pend'Oreille, based on the data for Castlegar. Predicted mean suspended solids concentrations and the upper 97.5th percentile concentration for the stations located downstream of Castlegar are shown in Table 5.6. In 1965 during construction, the Kootenay River had an average concentration of 1.5 mg/L suspended solids at Brilliant Dam (Appendix 3 Table A 3.3). Columbia River dilution with the Kootenay River inflow reduced suspended solids concentrations downstream of Castlegar as shown in Table 5.6. For example, mean suspended solids concentration at Cominco intake was calculated to be 6.9 mg/L during construction versus 12.7 mg/L at Castlegar.

Turbidity data reported by the West Kootenay Health Unit are presented in Table 5.5. These samples were taken at the Tadanac Water Treatment Plant from 1965 to 1968 during construction of the Hugh Keenleyside Dam. This intake is approximately 2 km downstream of the proposed Murphy Creek Dam. The results show that turbidity levels increased in September 1965 through January 1966 and peaked again in November 1967.

TABLE 5.5
TURBIDITY OF TADANAC UNTREATED WATER

TADANAC WATER TREATMENT PLANT TURBIDITY (JTU)			
	Min	Max	Avg
July 1965	2.0	6.3	3.2
August	1.6	12	3.9
September	1.9	20	10.1
October	0.1	19	6.3
November	N.D.	N.D.	N.D.
December	1.6	46	13.9
January 1966	1.3	49	10.7
February	1.4	9.5	4.5
March	1.6	4.3	3.5
April	1.2	2.8	2.0
May	1.4	2.6	2.1
June	2.1	3.9	2.9
July	2.2	4.2	3.1
August	1.6	3.1	2.2
September	1.6	3.1	2.2
October	1.3	4.6	2.8
November	1.3	9.0	5.4
December	1.3	9.0	4.8
January, 1967	1.2	7.0	3.3
February	1.3	3.5	1.9
March	1.3	8.5	2.6
April	0.5	2.5	1.3
May	1.3	6	3.1
June	1.6	9.5	4.5
July	6.0	8.0	7.0
August	2.0	6.0	2.7
September	2.0	7.2	5.5
October	1.8	7.2	3.7
November	4.0	30.0	12.5
December	1.1	8.3	4.2
January, 1968	1.3	5.5	3.3
February	2.0	6.0	3.7
March	1.7	9.5	2.5
April	1.7	2.6	2.1
May	1.9	2.8	2.2
June	4.7	9.5	5.0

TABLE 5.6
PREDICTED SUSPENDED SOLIDS CONCENTRATIONS FOR STATIONS DOWNSTREAM OF CASTLEGAR DURING HUGH KEENLEYSIDE DAM CONSTRUCTION: MAY 1965 - DECEMBER 1966

	Kinnaird (Stn. 3)	Cominco (Stn. 4)	Pend'Oreille (Stn. 5)
Mean Concentration, (mg/L)	8.4	6.9	8.6
Upper 97.5th Percentile (mg/L)	20.8	17.3	21.7

The Tadanac water treatment plant is rated at 2300 m^3 per day. Treatment consists of clarification and coagulation, filtration and chlorination.

Construction of the Hugh Keenleyside cofferdam was estimated to have reduced the channel width by 50% and would have caused increased velocities. [27] The estimated velocities at the Hugh Keenleyside Dam, shown in Table 5.3 for the fall and winter periods, were within the range of historic data for this river reach. The increased local velocities caused by construction of the cofferdam probably had no effect on sediment transport. Although spring and summer velocity data were not available for the construction period, they probably followed the pattern noted for fall and winter.

As previously discussed, B.C. Hydro monitored concentrations of suspended solids at the new BC Timber Ltd. intake, located upstream of the Hugh Keenleyside Dam site, during the construction period May 1965 to July 1967. [22] The monthly data for the new intake showed no apparent suspended solids increase due to construction (Appendix 3, Table A 3.1 to A 3.6). However, between 21 January 1966 and 16 February 1966, the placement of fill 488 m to 671 m upstream of the dam axis resulted in contamination of the BC Timber Ltd. water supply.

The contamination of the BC Timber Ltd. water supply was investigated by B.C. Hydro. Their analysis indicated that loads of fill material had created a density current which flowed 426 m upstream to the new intake. During periods when the velocity of the river flow exceeded 0.12 m/sec, there was no contamination of the BC Timber Ltd. water supply. [24] If the new BC Timber Ltd. intake had been located further upstream, no impact on water supply would have occurred.

Additional suspended solids concentration data were obtained for the Columbia River at Birchbank by the Federal Government Water Resources Branch. This station is located north of Trail. These data were provided from depth integrated sampling of the river from top-to-bottom-to-top. Their data were used to calculate sediment loading and because the sample was integrated to river bottom, higher maximum suspended solids concentrations were obtained than reported by B.C. Ministry of Environment and B.C. Hydro surface water quality surveys. The Water Resources Branch reported a maximum suspended solids concentration of 109 mg/L on 3 June 1968. However, during peak construction activity periods, they reported maximums of 75 and 28 mg/L in 1966 and 1967 respectively. Subsequent to dam construction they reported maximum daily values ranging from 51 to 16 mg/L.

IEC has used B.C. Ministry of Environment and B.C. Hydro surface water suspended solids concentration data to predict impacts associated with dam construction as their data bases were more extensive and historical sediment data are limited to only one station at Birchbank.

Revelstoke Dam Construction

Impacts attributed to construction of the Revelstoke Dam were evaluated to assess possible impacts on Columbia River water quality from the construction of the proposed Murphy Creek Dam. Water quality and flow data were availble for the periods prior to and during the Revelstoke Dam construction and are presented in Appendix 3, Table A 3.13 [28,29] Suspended solids data were used to evaluate:

- background water quality prior to the construction of the Revelstoke Dam;

- changes in water quality due to dam construction activities.

The B.C. Ministry of Environment monitored concentrations of suspended solids on an irregular basis in the Columbia River near Revelstoke, from 4 June 1975 to 10 February 1976, prior to the construction of the Revelstoke Dam. The preconstruction concentrations (3 samples) of suspended solids averaged 43 mg/L, but fluctuated between 3 mg/L and 86 mg/L. Preconstruction flows ranged between 1.40×10^7 m^3/day and $7.21 \times 10^7 m^3$/day, and averaged $5.14 \times 10^7 m^3$day.

The B.C. Ministry of Environment monitored concentrations of suspended solids at the sampling station near Revelstoke, located downstream of the Revelstoke Dam, during construction from 5 January 1977 to 7 October 1980. The dam was built in the dry and the principal construction activities included: clearing, coffer-dam construction and diversion tunnel construction.

Suspended solids concentrations, river flows, and the dam construction activities are presented in Figure 5.3. Overall, the level of suspended solids did not appear to change appreciably from background concentrations with the onset of construction. However, short term peak concentrations were recorded up to 310 mg/L. Suspended solid concentrations appeared to be independent of the variation of river flows as was found at the Hugh Keenleyside Dam. During the construction period, suspended solids near Revelstoke averaged 22 mg/L and ranged between 3mg/L and 151 mg/L. This interpretation must be qualified by noting that only 16 samples were collected. River flows averaged $6.23 \times 10^7 m^3$/dav and ranged between $1.96 \times 10^7 m^3$/day and $12.18 \times 10^7 m^3$/day.

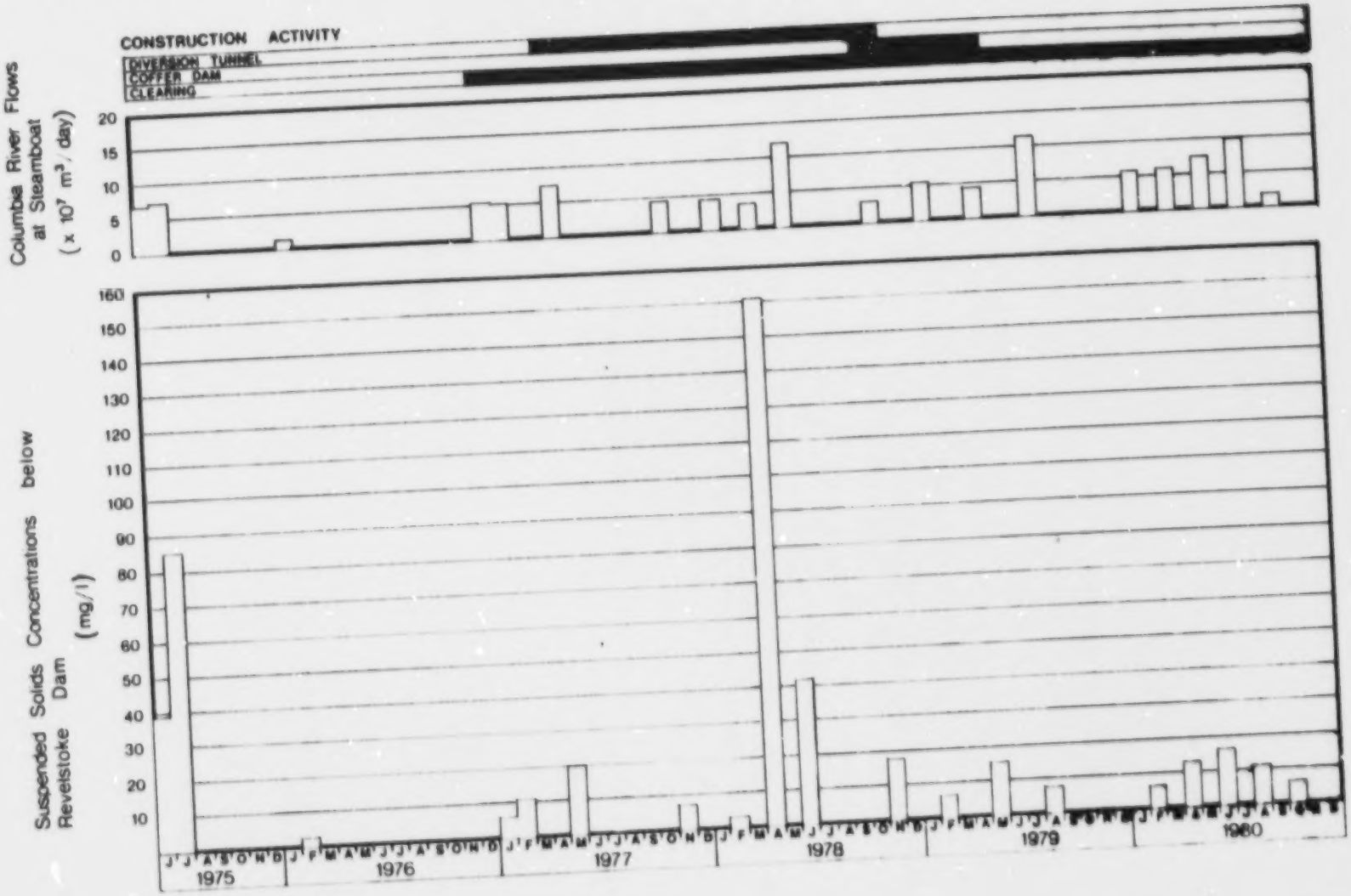
B.C. Hydro monitored the water quality of effluent discharges associated with secondary dam construction activities, including aggregate processing and concrete batching operations. They measured high (600-26,000 mg/L) concentrations of suspended solids, and on one occasion, high (3.0 mg/L) ammonia concentrations in the batch plant settling pond. [30] The pond location on the riverbank provided only minimal settling before discharge to the river. Suspended solids and ammonia effects on Columbia River water quality were negligible due to an average ten thousand-fold dilution.

Concentrations Suspended Solids and Flows Below Revelstoke Dam

vs

Activity Associated with Revelstoke Dam Construction

5-3



5.1.4 Suspended Solids During Murphy Creek Dam Construction

As the Revelstoke data base during construction was limited, the predicted impacts are based on data collected at Hugh Keenleyside Dam. Furthermore, the data collected during Hugh Keenelyside construction were obtained from surveys specifically designed to monitor construction impacts.

Suspended solids data, collected by the B.C. Ministry of Environment [26], at Birchbank, from January 1973 to April 1979, were used to establish preconstruction levels for the Murphy Creek Project.

Maximum predicted downstream suspended solids concentrations during Murphy Creek Dam construction, presented in Table 5.6, were calculated on the assumption that an increase similar to that attributable to the Hugh Keenleyside Dam construction could be added to the preconstruction concentration for Birchbank. On this basis, the average downstream levels of suspended solids could be 13.7 mg/L and the upper 97.5th percentile concentration could be 33.4 mg/L, during the construction of the Murphy Creek Dam. However, it is understood that the proposed construction of Murphy Creek Dam would not include dumping of fill in the river, and construction would be in the dry, therefore turbidity increases should be less.

It is suspected that most solids and turbidity generated at the Murphy Creek damsite will originate from erosion of the watershed's terrain adjacent to the creeks caused by local precipitation events in the vicinity of the construction site. In addition, erosion in the Murphy Creek and Billy Creek watershed represent a potential source of suspended solids. Murphy Creek has been identified by B.C. Hydro as a potential source for till for construction and Billy Creek has been identified as a spoil area.

Many studies have demonstrated the impact of suspended solids on plankton, benthos and fish due to light attenuation, sedimentation, and abrasion. [31-37] Studies also have shown that impacts are minimized if concentrations are low, if river velocities are sufficient to prevent silt settlement, or if increases in suspended solids levels are temporary. [35-37]

Criteria for the protection of aquatic communities from the impacts of suspended solids are presented in Table 5.7. Based on these criteria, it is predicted that the construction of the Murphy Creek Dam would produce no harmful effects on downstream fisheries as a result of predicted elevated levels of suspended solids presented in Table 5.8. There could be some low level impacts at the upper 97.5th percentile concentration, but these effects would be temporary. It is noted that the terms of reference of this study do not include impact assessment of the project on aquatic resources as this evaluation will be performed by other B.C. Hydro Consultants. In addition, a separate study is investigating project impacts on downstream water uses.

5.2 Operational Impacts

The length of the reservoir relative to its width, the high flow and the sinuous nature of the banks will result in the waters of the reservoir being relatively well mixed as they flow through the impoundment. The flow of water through the reservoir will be relatively uniform throughout the water mass. Major replenishment of the reservoir will occur from upstream sources of high water quality. Separation of the water into discrete regimes and therefore different quality is not expected. Water flowing through the turbines and over the spillways will be of relatively uniform quality and will meet provincial water quality standards of the Province of British Columbia.

The following specific impacts are discussed relative to pertinent water quality parameters.

5.2.1 Nitrogen

The impact of the Murphy Creek Dam on the nitrogenous water quality of the reservoir is expected to be minimal. The average daily loading at any point in the proposed reservoir will fluctuate in proportion to the river flow, but as no significant additional upstream nitrogen inputs are comtemplated, the average concentrations of nitrogen in the main Columbia and Kootenay influent flows would not change significantly and should represent average concentrations entering the proposed reservoir.

TABLE 5.7

SUSPENDED SOLIDS CRITERIA

Concentration Suspended Solids (mg/L)	US Level of Protection[1]	Expected Impacts on Freshwater Fisheries[2]
0 - 25	High	No harmful effects. Excellent fisheries.
25 - 80	Moderate	Low to moderate effects. Good to moderate fisheries.
80 - 400	Low	Moderate to high effects. Moderate to poor fisheries.
G 400	Poor	Severe effects. Poor fisheries.

G = greater than

Reference

1 1972, Water Ouality Criteria, National Academy of Science and National Academy of Engineering.

2 1965, European Inland Fisheries Advisory Commission.

TABLE 5.8

PREDICTED DOWNSTREAM LEVELS OF SUSPENDED SOLIDS DURING CONSTRUCTION OF MURPHY CREEK DAM

Measured		Predicted	
Mean Preconstruction Concentration, (mg/L)	Upper Preconstruction 97.5th Percentile (mg/L)	Mean Downstream Concentration (mg/L)	97.5th Percentile (mg/L)
2.2 ± 2.0	6.2	13.7 ± 10.1	33.4

[1] Preconstruction levels in Columbia River at Birchbank, Jan. 1973 - Apr. 1979 [18]

Existing high total nitrogen discharges (90th percentile) from BC Timber Ltd. were evaluated using the predicted extreme low flows in the Columbia River. At low flows in the river, discharges from BC Timber Ltd. would result in a total nitrogen concentration of 0.3 mg/L after initial dilution of 25:1. At complete mixing at low flow (142 m^3/sec) the total nitrogen concentration in the river would decrease to 0.16 mg/L. This level is comparable to existing levels measured at Birchbank.

5.2.4 Phosphorus

The impact of the Murphy Creek Dam on phosphorus water quality of the reservoir is expected to be minimal. Loadings at any point will fluctuate according to influent flows but average concentrations should be similar to those exhibited presently. Limitations on phosphorus concentrations in flowing water have been set at 0.1 mg/L to prevent nuisance conditions. (3)

Existing maximum phosphorus discharges from BC Timber Ltd. have been combined with predicted low river flows. Dilutions would result in total phosphorus concentrations in the river of about 0.05 mg/L after initial mixing. This level is less than the guideline for phosphorus concentrations in flowing water. At complete mixing at low flow, the resultant concentration would be about 0.01 mg/L, well below the guideline value of 0.1 mg/L.

5.2.5 Colour

Discolouration of the river in the zone downstream of the BC Timber Ltd. diffuser pipe to Castlegar occurs under present discharge and low river flow conditions. Secondary treatment of mill effluent is not liable to reduce colour discharges and thus discolouration of the river at low flow conditions is expected to continue. Mass balance and predicted dilution calculations indicated that, at high colour level discharges, river flows in the dilution zone would have to be greater than 1500 m^3/sec to approach the acceptable limit of 15 true colour units in the river zone from the discharge to Castlegar.

5.2.6 Toxicity

If BC Timber Ltd. meet the level A toxicity requirements (i.e. 96 hr LC_{50} = 100%), at a minimum dilution of 25:1 predicted at plume boil up, the effluent would not be expected to show sub lethal toxic effects, according to general guidelines relating to effluents that do not contain persistent contaminants. Sub lethal effects, other than flesh tainting, are not expected to be manifested at effective effluent contentrations less than 10% of the 96 hr LC_{50}.

5.2.7 Dissolved Gases

Since dissolved gas supersaturation occurs at present, downstream from the Hugh Keenleyside Dam, predicted operating levels of the Arrow and Murphy Creek reservoirs were examined for both Regime 1 and Regime 2 operating conditions. With the powerplant installed at the Keenleyside dam, all flows through the Keenleyside Dam would be submerged, either through the turbines or through the low level ports at mean operating regimes with the exception of 1.5% of flow during Regime 1 and 3% of flow during Regime 2 operation. These percentages can be compared to 68% of flow passed over the spillway under simulated existing conditions. Thus, the potential for dissolved gas supersaturation in the reservoir downstream from the Keenleyside Dam would be greatly reduced under the predicted operating conditions of Regime 1 and 2.

5.2.8 Dissolved Oxygen

The potential for exchange of dissolved oxygen between the atmosphere and the river was calculated using an exchange coefficient developed by O'Connor and Dobbins. [6]

The change in concentration of dissolved oxygen is given by:

$$Cs - Cx = (Cs - Co)e^{-k_2 x/u}$$

Where: Cs is the concentration at saturation;
Cx is the concentration at any distance downstream;
Co is the concentration at the starting point;
x is the distance downstream;
k_2 is the exchange coefficient and;
u is the stream velocity.

Using the baseline data summarized in Table 4.6 in Section 4.2.5, the change in dissolved oxygen concentration was calculated for the reach from the confluence of the Kootenay and Columbia River to Birchbank for existing conditions. The statistically calculated change under present conditions was 7%.

Using the conditions given in Table 4.6 at the confiuence of the Columbia and Kootenay rivers and predicted conditions of the reservoir after construction of the Murphy Creek Dam and neglecting changes in temperatures, the dissolved oxygen concentration and percent saturation were predicted at the dam site.

The changes in percent saturation values from the confluence to the dam site were compared and no difference in percent saturation was noted. This indicated that, neglecting temperature changes, the operation of the Murphy Creek Dam would have no effect on dissolved oxygen saturation concentrations through the reach of river from the confluence of the Columbia and Kootenay rivers to the dam.

The potential dissolved oxygen sag was examined in the reach of river downstream from the discharge of the BC Timber Ltd. mill. The average BOD_5 concentration from the mill was calculated to be 193 mg/L at an average flow rate of 120,000 m^3/day. At similar loadings, the B.C. Ministry of Environment report concluded that no significant reduction in dissolved oxygen occurs downstream from the mill. (1)

The Streeter-Phelps equation was used to determine if an oxygen sag would result from existing high BOD discharges from the mill with a low predicted river flow. The equation predicts the reduction in oxygen concentration due to organic matter demand. The mathematical treatment is presented in Appendix 2 and the reductions for various distances downstream from the BC Timber Ltd. discharge are presented in Table 5.9. These reductions are based on the 90th percentile of BOD_5 concentrations from the mill @ 300 mg/L.

TABLE 5.9
REDUCTION IN OXYGEN CONCENTRATION DOWNSTREAM FROM BC TIMBER LTD. DUE TO ORGANIC MATTER DEMAND AT EXTREME RIVER CONDITIONS AND 20 ° C.

Downstream From Discharge (km)	Reduction Regime 1 (mg/L)		Reduction Regime 2 (mg/L)	
	Low Flow	Low Elev.	Low Flow	Low Elev.
0.5	0.15	0.09	0.15	0.01
1	0.29	0.17	0.29	0.01
2	0.55	0.33	0.55	0.03
3	0.8	0.49	0.08	0.04
4	1.03	0.64	1.03	0.06
5	1.24	0.78	1.24	0.07
6	1.44	0.91	1.44	0.08
7	1.62	1.04	1.62	0.09
7.7 (Confluence with Kootenay)	1.74	1.12	1.74	0.1
9	0.29	0.21	0.32	0.02
10	0.32	0.23	0.35	0.03
15	0.45	0.32	0.49	0.04
20	0.56	0.41	0.60	0.05
25	0.65	0.49	0.7	0.06
30	0.73	0.55	0.78	0.07
30.7	0.74	0.56	0.79	0.07

The maximum predicted decrease in dissolved oxygen (DO) in the river is calculated to be 1.7 mg/L at 20 ° C. To maintain a DO level at Castlegar of about 5 mg/L, the recommended minimum concentration to maintain good fish populations, [1] upstream oxygen saturation in the river could be as low as 73% at 20 ° C. Lower saturation values could be present at lower temperatures associated with withdrawal from the hypolimnion of Arrow Lakes Reservoir and still maintain the required minimum in the river. After the confluence with the Kootenay River, the decrease is less pronounced due to dilution from the Kootenay.

If the BC Timber Ltd. mill installs secondary treatment and meets the Level A objectives, BOD discharges would average around 50 mg/L, much less than used in the preceding calculations. Predicted DO reductions would be correspondingly lower at the low flow conditions.

5.2.9 Thermal Stratification

Calculated net solar radiation was used to analyze thermal stratification in Murphy Creek reservoir. Thermoclines are usually formed when the total heat flux into the surface water layer exceeds the total heat flux from the layer. This situation results in the heating of the surface layer and the resultant density difference provides stability.

The analysis of potential thermal stratification was undertaken by using the following approach. A water column within the Murphy Creek reservoir of unit surface area was divided into two portions, a surface layer of unit depth and an underlying portion. Flow was assumed to occur through the underlying layer. A vertical exchange flow to the surface layer of one-tenth the horizontal flow was assumed, based on an estimate of the vertical component of turbulent flow. The solar heat flux was applied to the surface layer and was assumed to heat only that layer. The advective heat flux into the surface layer was taken as the product of the average temperature over the month in the underlying water, the heat capacity and the exchange flow.

The solar heat flux was calculated as a fraction (parts per million) of the advective heat flux. If the calculations indicated that it was an appreciable portion of the

advective flux, the potential could exist for heating of the surface layer and subsequent reservoir stratification.

Since the reservoir would be a run-of-the-river type with residence times on the order of days, the worst case condition considered in the analyses were a combination of maximum daily solar heat fluxes and low flow and/or low elevation in the reservoir. Only the reach of the reservoir downstream from the confluence of the Kootenay River was examined.

Low flow and low elevation conditions for Regimes 1 and 2 for the month of July were available from the BC Hydro simulation of reservoir operation. Residence times of water in the reservoir reach from the confluence to the Murphy Creek Dam were calculated. Advective heat fluxes from the underlying water were applied to the surface layer over the calculated residence time.

Based upon daily monthly mean values for net radiation [7], maximum daily values were estimated assuming that the variance of daily values within a given month could be estimated statistically from the variance of the mean daily values for a month over the years of record.

The maximum estimated (99th percentile) daily net solar heat flux for the month of July was calculated to be 1.73 times the average daily flux based on an analysis of the Summerland data. These maximum daily fluxes were then applied to the surface layer of the reservoir over the calculated residence times.

The conditions used and results of the calculations are given in Table 5.10. The highest value listed in 32.44 ppm for Regime 1 at low flow.

It is unlikely that sufficient warming of the surface layer and subsequent stratification would result from incident solar readiation since residence times in the reservoir are relatively short.

TABLE 5.10

COMPARISON OF HEAT FLUXES TO

SURFACE LAYER OF RESERVOIR IN JULY - AUGUST

Parameter	Regime 1 Low Flow	Regime 1 Low Elevation	Regime 2 Low Flow[i)]
Reservoir Elevation (m)	424	423	424
Reservoir Depth (m)	12.4	11.2	12.3
Reservoir Width (m)	380.6	369.6	379.7
Reservoir Length (m)	23,000	23,000	23,000
Flow (m^3/sec) [ii)]	579	2659	1095
Residence Time (D)	2.17	0.41	1.135
Flow in Underlying Area per Residence Time (m^3)	2.852×10^5	2.548×10^5	2.828×10^5
Advective Flux to Surface Layer (kcal) (= Cp x 0.1 Q x T where T = 15.1°C)	4.307×10^8	3.847×10^8	4.27×10^8
Solar Flux per Residence Time (kcal) (= $1.73 \times 3.72 \times 10^3$ Res. Time x Unit Area)	1.397×10^4	2.639×10^3	7.304×10^3
Solar Flux as ppm of Advective Flux	32.44	6.86	17.11

Note:

i) Simulation for Regime 2 did not yield elevation less than 424 m.

ii) Downstream of confluence.

5.2.10 BC Timber Ltd. Effluent Dispersion

A mathematical model was developed based on conductivity data (see Appendix A2.3) to predict the behavior of the BC Timber Ltd. effluent discharge after the construction of the Murphy Creek Dam. The model considers the initial dilution, while the plume rises to the surface, and the diffusion of the surfaced plume in the river. Conductivity and temperature were measured at different depths and distances downstream from the BC Timber Ltd. diffuser.

The equations used to simulate the initial dilution were based on graphs from the Work Book of Thermal Plume Prediction, Submerged Discharge, Shirazi and Davis, EPA-R2-72-005a [11]. This analysis enabled IEC to calculate the distance downstream the plume will surface and the dilution for given flows. Subsequent dilution of the surfaced plume was calculated using a dispersion expression developed from linear regression of the field study data. Equations are given in Appendix 2.3.

Two operating regimes currently are under consideration for joint operation of the Murphy Creek and Hugh Keenleyside dams. Based upon 40 years of river flow data, B.C. Hydro has predicted minimum, average and maximum elevations and flows for both Regime 1 and Regime 2 operating schedules throughout the year. [43,44] As BC Timber Ltd. effluent dispersion will increase with both increasing flow and increasing elevation, IEC has used the combination of minimum flow and elevation to assess maximum potential impact.

The critical combinations for each operating regime are:

	Flow (m^3/s)	Elevation (m)
Regime 1		
Extreme Minimum Flow	142	424.0
Extreme Low Water Level	153	420.5
Average Minimum Monthly Flow (June)*	595	424.0

* generally minimum occurs in month of June therefore, this is average of 40 June values.

	Flow (m^3/s)	Elevation (m)
Regime 2		
Extreme Minimum Flow	142	424.0
Extreme Low Water Level	520	419.8
Average Minimum Monthly Flow (November)*	658	424.0

* generally minimum occurs in month of November therefore, this is average of 40 November values.

Figures 5.4 to 5.6 show the model predictions for downstream distance where the plume surfaces for varying conditions of river flow, elevation and temperature. Figure 5.7 shows the predicted behaviour for the existing regime in the river. The degree of effluent dilution at the point of initial surface impingement of the plume is shown for possible future conditions in Figures 5.8 to 5.10. The predicted behaviour in plume dilution for the existing river condition is shown in Figure 5.11.

As biological treatment of the mill effluent prior to discharge would reduce the temperature, the predicted effect of an $8^{o}C$ reduction in effluent temperature (e.g. discharge to river at $20^{o}C$) has also been shown in the figures.

The following observations can be made from the information in the figures.

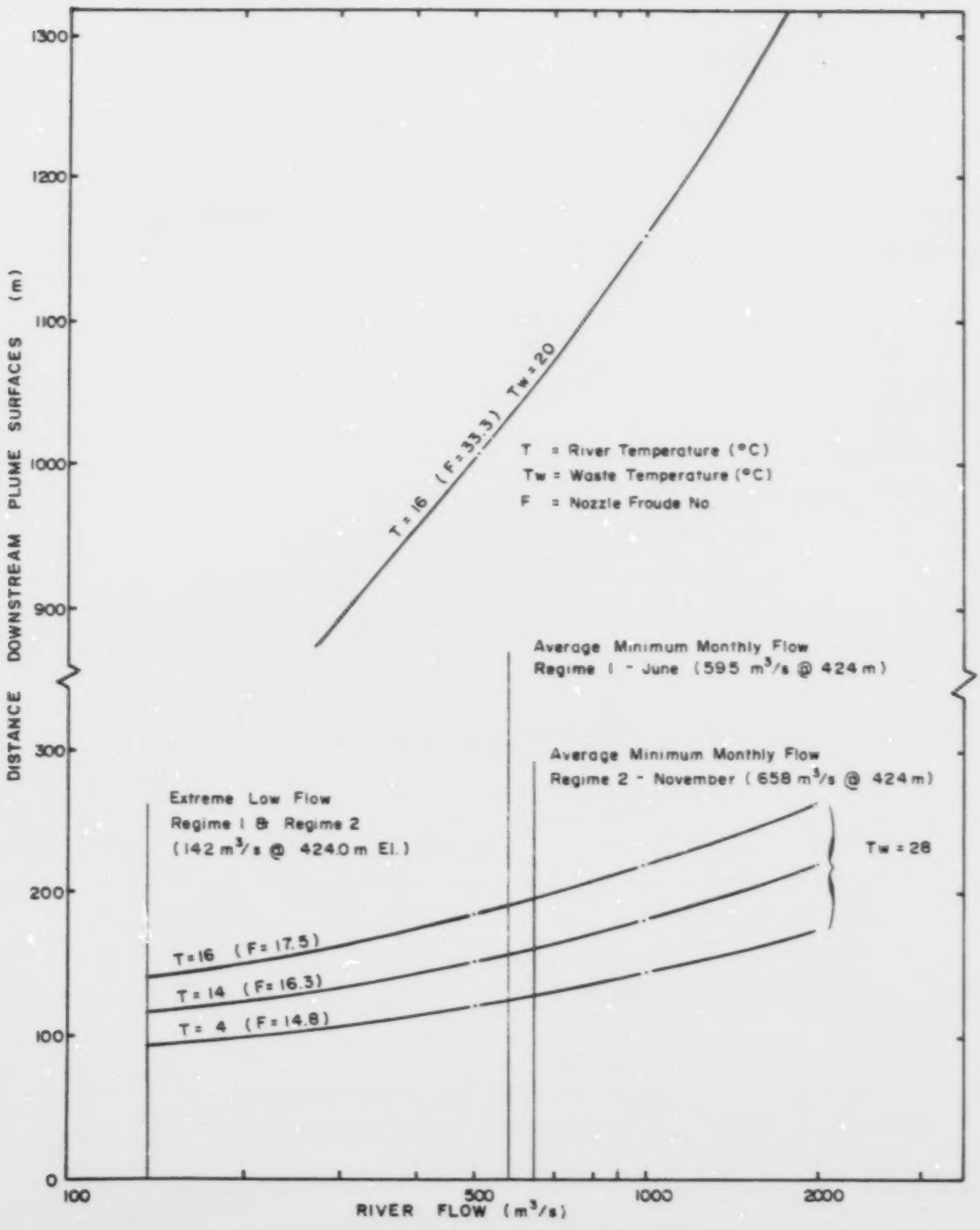
- The point of surface impingement of the plume would normally be 100 to 200 metres downstream of the diffuser. This could decrease occasionally to as little as 70 metres during periods of extreme low flow.

- Initial plume dilution at surface impingement would be a minimum of 25:1 to 30:1 even during conditions of extreme low flow and low elevation. The predicted conditions of initial dilutions for average minimum monthly flows range between 40:1 to 70·1 for Regime 1 and 50:1 to 80:1 for Regime 2.

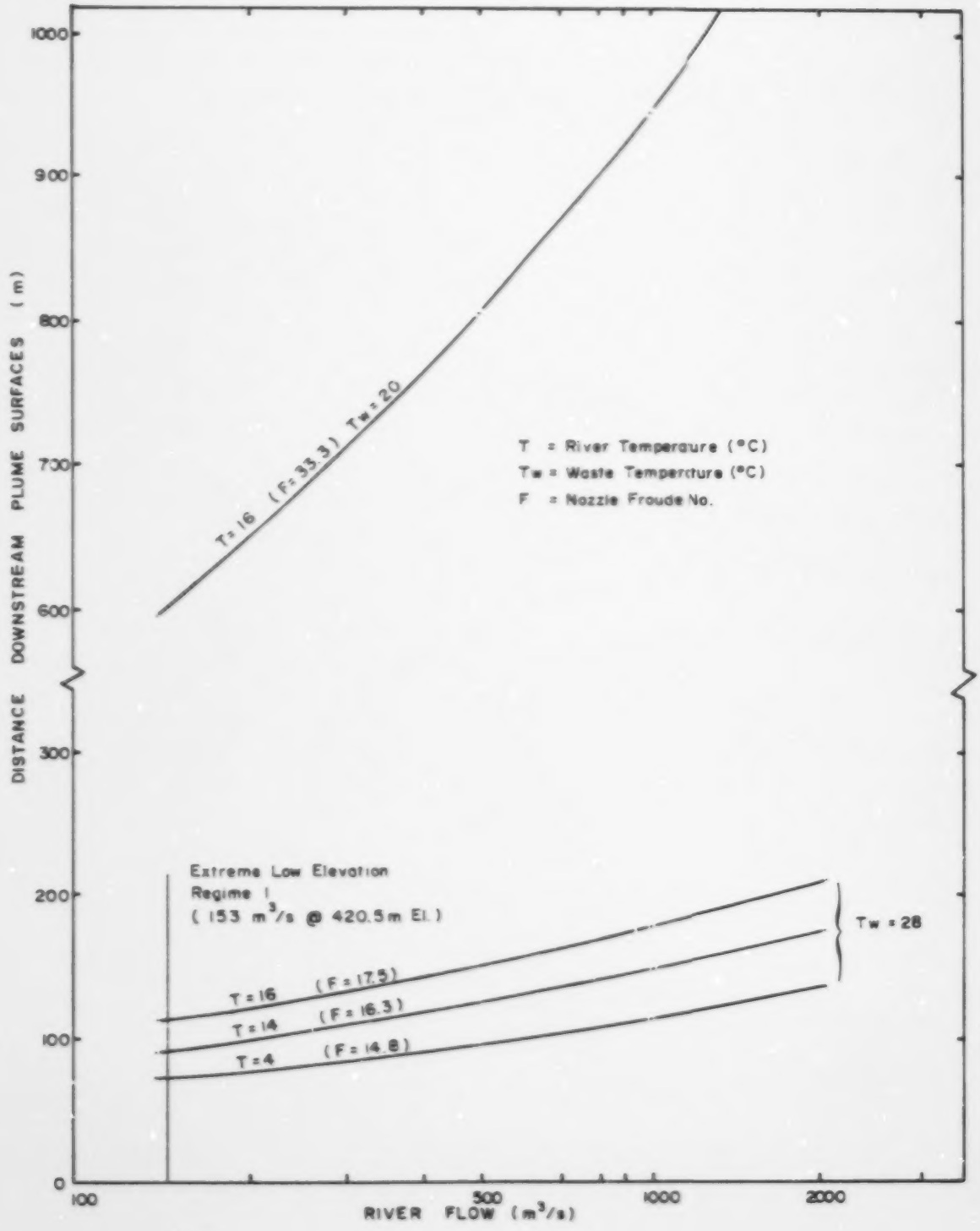
- Cooling of the mill effluent to $20^{o}C$ prior to discharge could increase the distance downstream at which the plume would reach the surface, to between 600 and 1000 metres for both Regimes 1 and

B.C. Timber Ltd. Plume Model
Distance D/S Plume Emerges
vs River Flow
El. 424 m

5.4



B.C. Timber Ltd. Plume Model
Distance D/S Plume Emerges
vs River Flow
El. 420.5 m



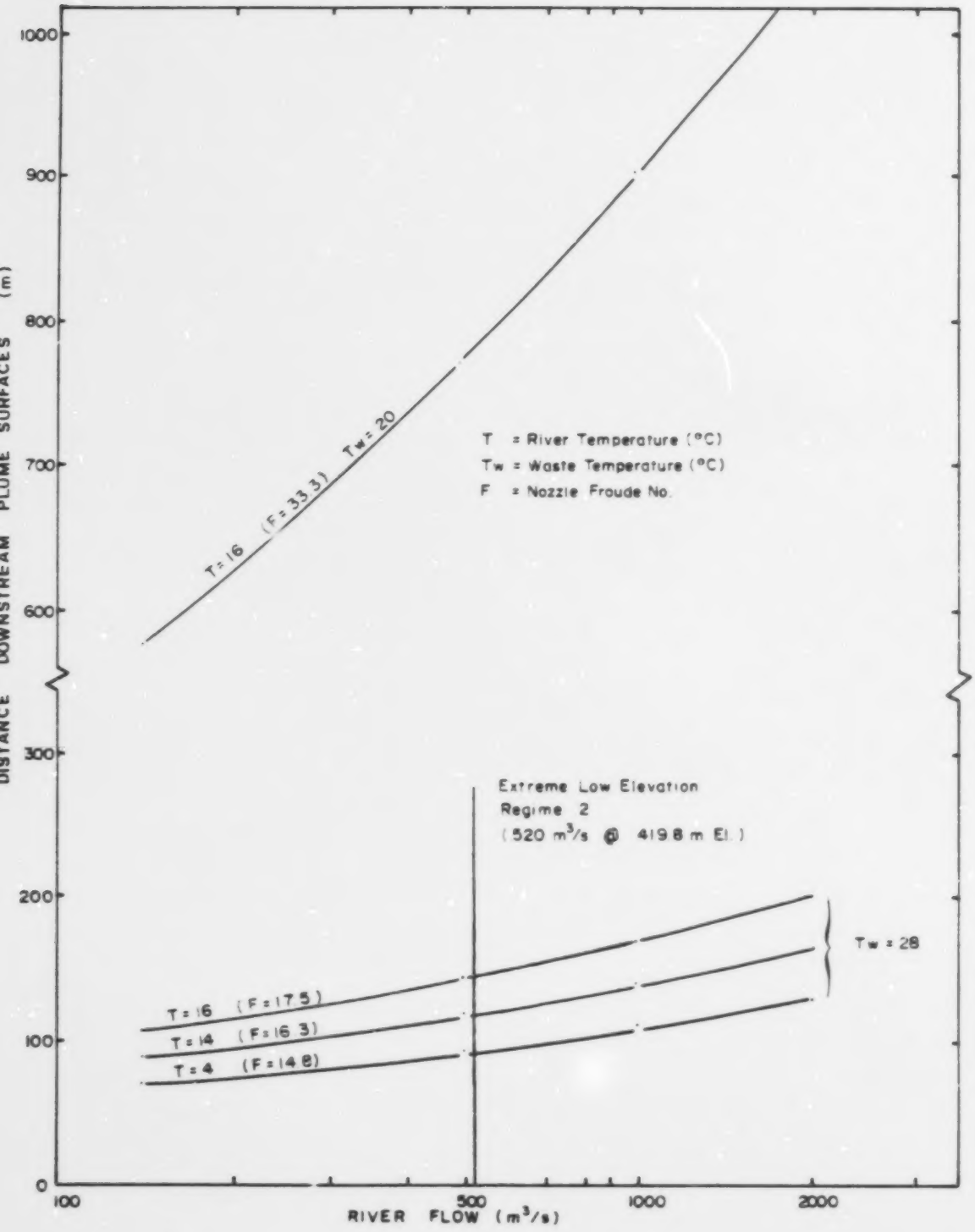
B.C. Timber Ltd. Plume Model

Distance D/S Plume Emerges

vs River Flow

El. 419.8 m

5.6

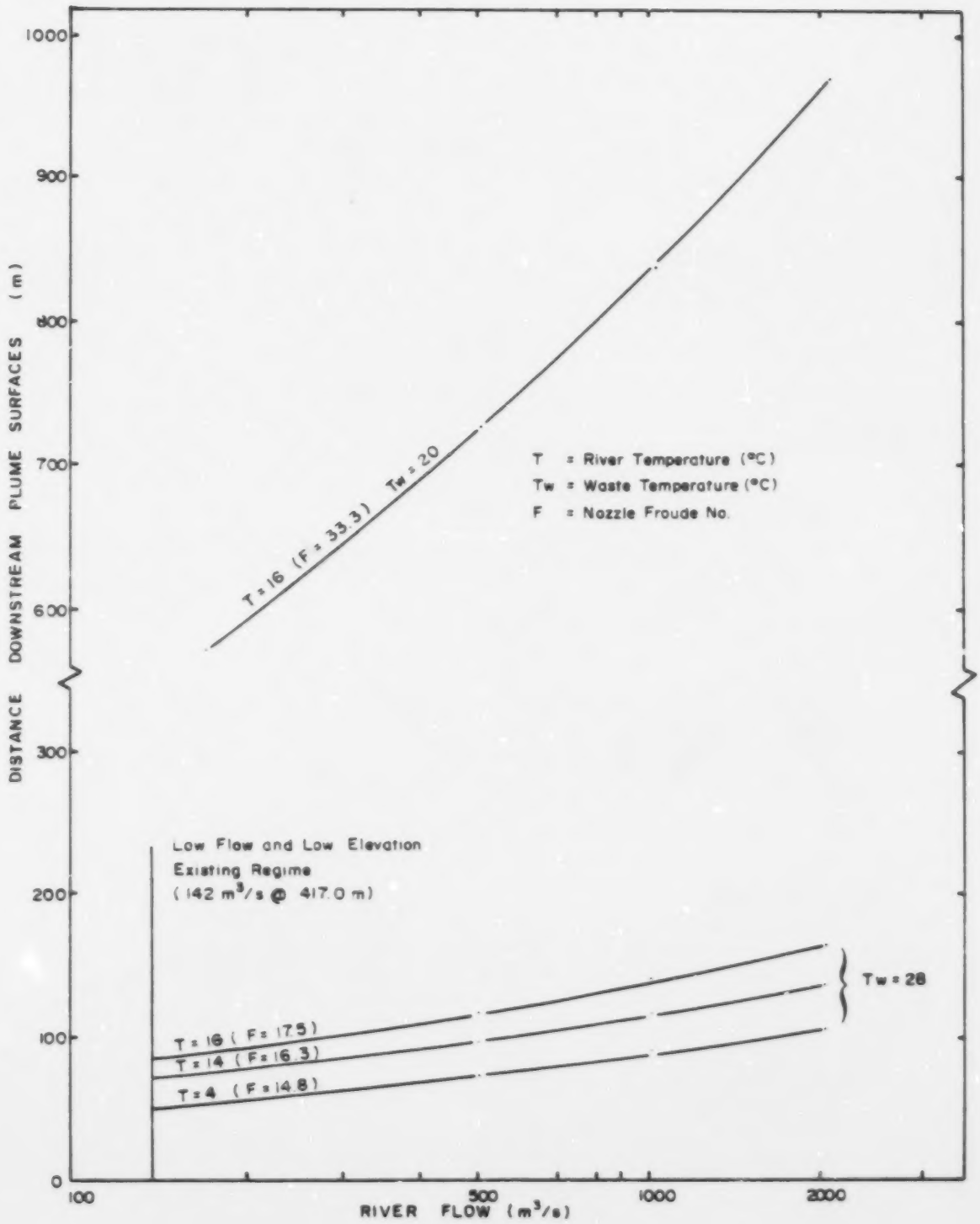


B.C. Timber Ltd. Plume Model

Distance D/S Plume Emerges

vs River Flow

El. 417 m

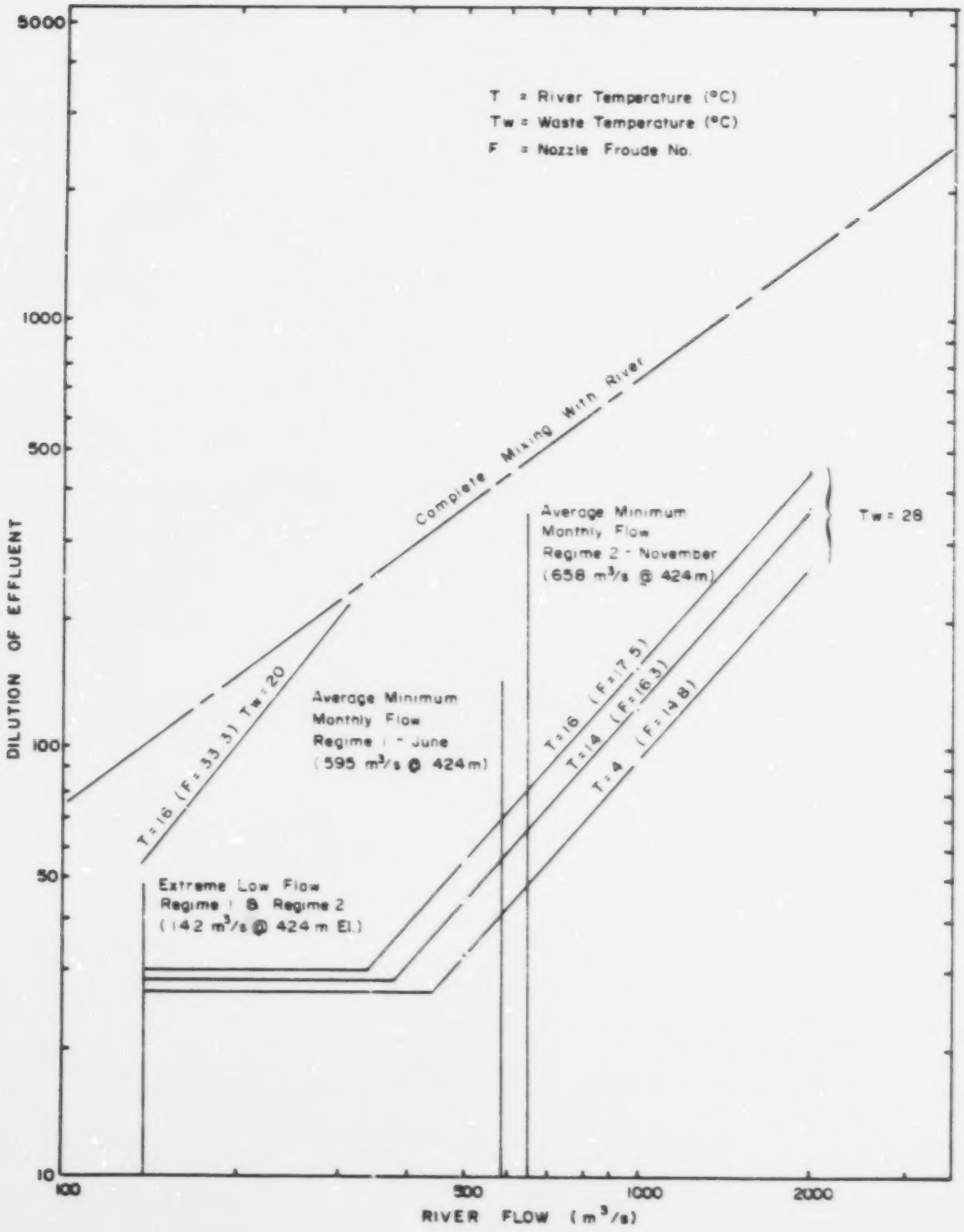


B.C. Timber Ltd. Plume Model

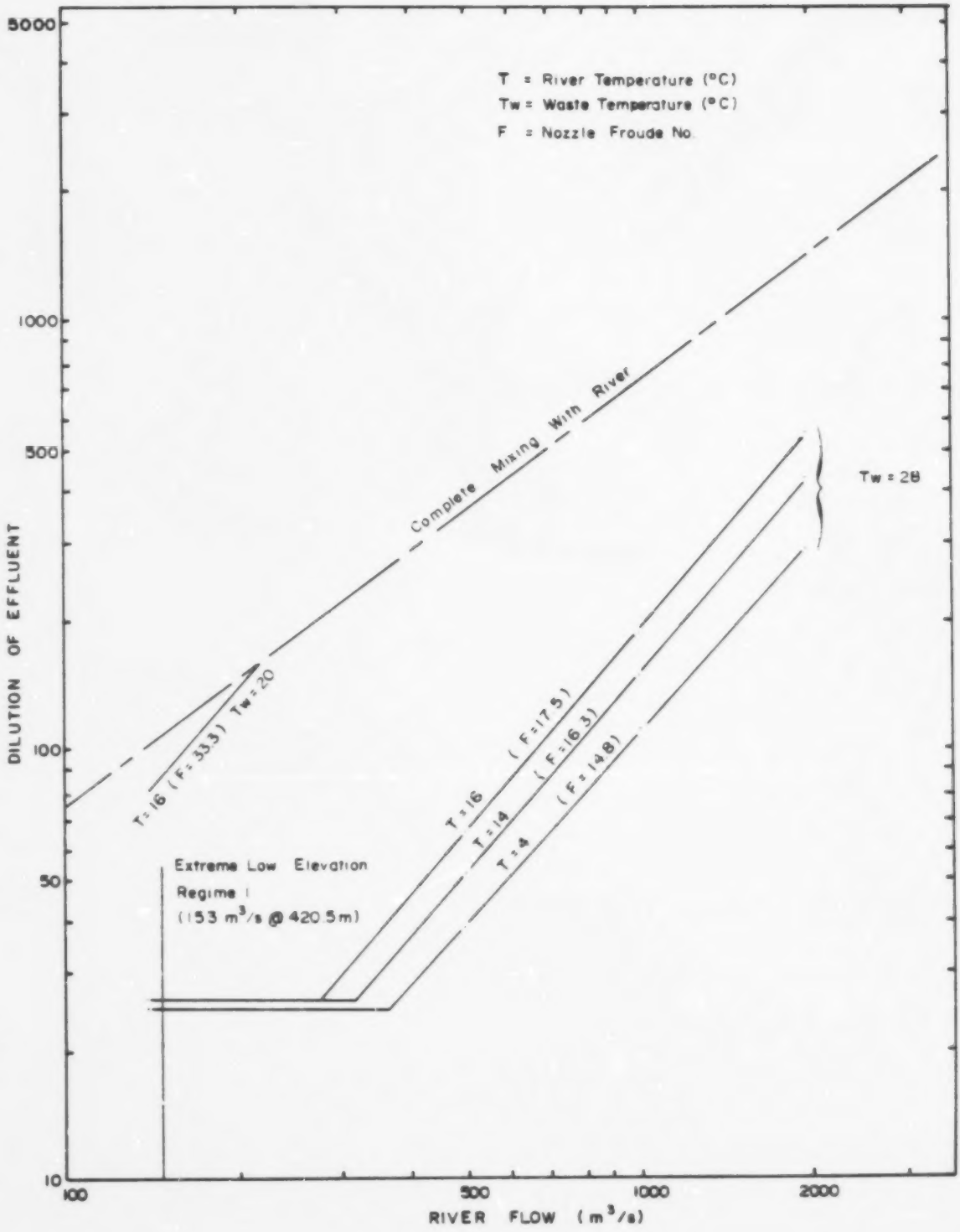
Dilution of Plume "Boil-Up"

vs River Flow

El. 424 m



B.C. Timber Ltd. Plume Model
Dilution of Plume "Boil-Up"
vs River Flow
El. 420.5 m

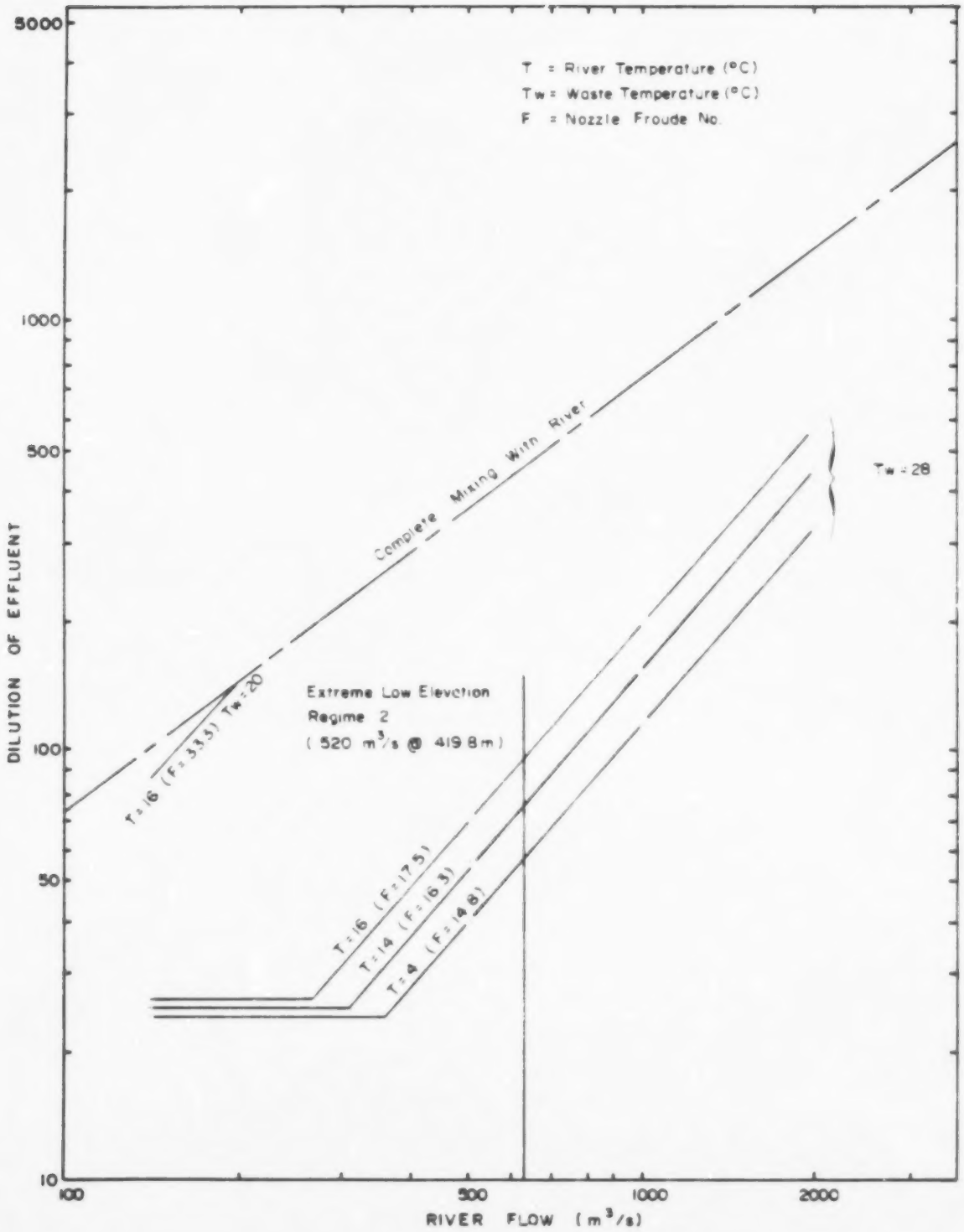


B.C. Timber Ltd. Plume Model

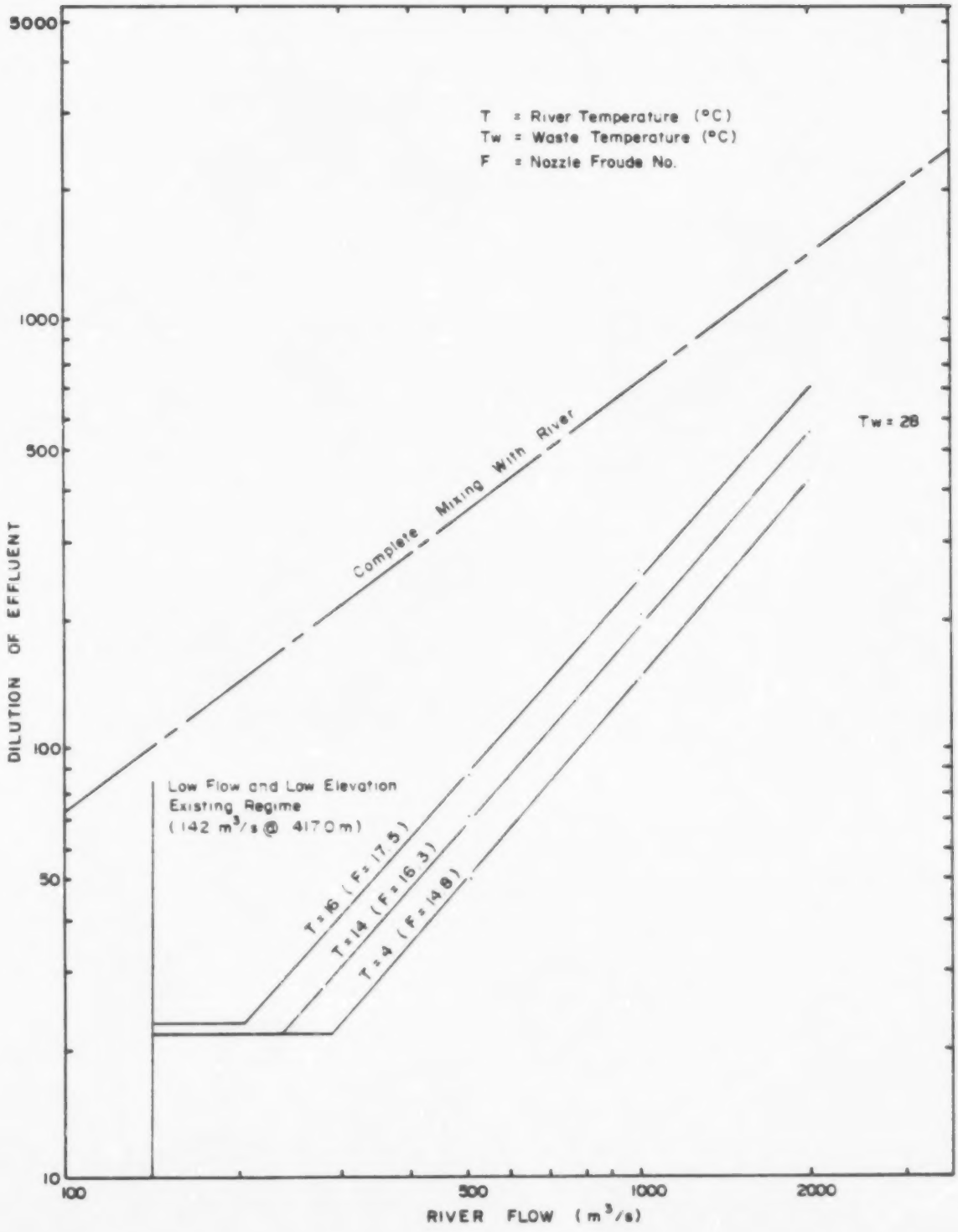
Dilution of Plume "Boil-Up"

vs River Flow

El. 419.8 m



B.C. Timber Ltd. Plume Model
Dilution of Plume "Boil-Up"
vs River Flow
El. 417 m



2 depending on river flow and elevation. Under most flow conditions these would allow the mill to become completely mixed with total river flows by the time it reaches the surface. This would provide dilution varying from 100:1 at extreme low flow to more than 1000:1 at flows approaching 2000 m^3/s.

- Maintaining the water elevation between roughly 420 m and 424 m as proposed for Regimes 1 or 2 would increase the dilutions of the mill effluent during low flow periods compared to the present situation.

From equations given in Appendix A2.3, dilutions under various reservoir elevations and flows were calculated as shown in Table 5.11 for a point 5000 m downstream of the diffusers approximately at the City of Castlegar. This table shows that effluents will not totally dilute during extreme low flow conditions and will be between 40 and 60 percent towards complete dilutions at other times.

Ponding of the BC Timber Ltd. diffuser plume probably has resulted from low flows in the Columbia River upstream of the Kootenay River compared to flows in the Kootenay River itself. A comparison of the ratio of Columbia River flow to Kootenay River flow indicated that under present conditions a lower relative flow in the Columbia than would occur under Regime 1 or Regime 2. This would imply a reduced ponding tendency at Castlegar with installation of the dam and operation at predicted conditions.

In summary, under either Regime 1 or Regime 2 operation the plume would surface between 70 and 200 m downstream of the BC Timber Ltd. effluent diffusers and would have a minimum dilution of 25:1 to 80:1 during low flows. Cooling the effluent to 20°C would considerably increase these values. BC Timber Ltd. effluent would be diluted at least 50% of the theoretical possible dilution at a point 5000 m downstream of the diffusers. The installation of the Murphy Creek Dam and operation under either Regime 1 or Regime 2 mode should reduce ponding action in the Columbia River upstream of the confluence with the Kootenay River.

TABLE 5.11
CALCULATED EFFLUENT DILUTIONS
5000 M FROM DIFFUSER (F = 16.3)

Flow (m^3/s)	Reservoir Elevation (m)	River Velocity (m/s)	Predicted Dilution	Theoretical Total Dilution
2000	424.0	0.524	800	1430
	N/A	N/A	N/A	N/A
1000	424.0	0.262	330	715
	419.8	0.408	370	715
500	424.0	0.131	140	357
	419.8	0.204	150	357
140	424.0	0.037	100	100
	419.8	0.057	93	100

5.2.11 Suspended Solids/Turbidity

As settleable suspended solids deposit upstream of the proposed dam in Hugh Keenleyside and Brilliant Dam reservoirs, it is unlikely that measurable deposition will occur in the Murphy Creek reservoir. Any settleable suspended solids discharged from BC Timber Ltd. will deposit in the Murphy Creek reservoir. Furthermore, suspended sediments from streams discharging to the Murphy Creek reservoir will accumulate. Studies by B.C. Hydro[38] have predicted the time taken for sediments to occupy the dead storage volume and half of the live storage volume to be in excess of 3,000 years.

As discussed previously, the principal suspended solids impacts, will be associated with the construction phase of the project and mitigating measures will be necessary to minimize this impact.

6.0 MITIGATION

As discussed in the previous section, impacts of the proposed development were predicted for the construction and operational phases of the Murphy Creek Dam. The following mitigative measures, if implemented, will minimize environmental impacts on water quality caused by the proposed development.

6.1 Construction Mitigative Measures

It is expected that during the construction of the Murphy Creek Dam downstream levels of suspended solids in the Columbia River could be elevated due to cofferdam construction and removal, river diversion aggregate washing, runoff and erosion from local creeks chosen as construction material sources.

To minimize elevated sediment concentrations and loadings it is recommended that the construction area of the Murphy Creek Dam should be set up as a closed system in which water used in construction processes, i.e. gravel washing, concrete mixing and washing, etc., would be recycled. A suitably designed settling pond could be built to intercept all extraneous construction process effluents.

The location of proposed dump sites for construction waste materials should be investigated to ensure that aquatic resources are protected from any releases from the sites.

To ensure minimum downstream concentrations of turbidity and suspended solids, all storm drainage from construction areas should be discharged upstream of the damsite. Downstream water users should be advised by B.C. Hydro that suspended solids and turbidity levels will be elevated particularly in year 1 to year 5.75. In addition, elevated levels may occur during periods of heavy rain at the construction site and aggregate source sites.

6.2 Operational Mitigative Measures

Operational impacts on water quality have been discussed and have been predicted to be minimal. However, dissolved gas supersaturation could occur in the Columbia River if the spillway at the Hugh Keenleyside Dam is used. Downstream supersaturation could be lessened by maximum use of the low level ports at the Keenleyside Dam which presently can only be used when the differential head between the Arrow Lakes Reservoir elevation and the tailwater elevation is less than 9 m. Present operations require use of the spillway for about 68% of the total flow. Predicted future operations would require spillway flow for only 1.5% and 3% for Regime 1 and Regime 2 respectively, thus, greatly ameliorating the potential for gas supersaturation in the reach of river from the Keenleyside to Murphy Creek Dam.

Dispersion of the BC Timber Ltd. effluent could be enhanced if the effluent is discharged at lower temperatures. However, it is understood that BC Timber Ltd. propose to expand the mill and to provide improved effluent treatment. Following completion of this program, river water quality downstream of the mill will be improved.

7.0 RECOMMENDATIONS

This study has revealed a shortcoming in the technical literature on environmental impacts on water quality associated with dam construction. Only limited data were available in British Columbia and the data base for projects outside the province was minimal.

To assist B.C. Hydro investigate proposed water quality impacts on future dam/reservoir projects and to evaluate the accuracy of the predictions made in this study, is recommended that a comprehensive baseline and construction water quality monitoring program be designed and implemented for the proposed Murphy Creek project. The program should include weekly monitoring of flow, suspended solids, settleable suspended solids, particle size distribution, turbidity and secchi disc measurements at several upstream and downstream stations from Murphy Creek Dam. Moreover, measurements of sediment bed load transport should be undertaken seasonally as part of the program. During periods of intense local precipitation and/or intense construction activity it is recommended that daily monitoring be initiated. The comprehensive baseline program should be initiated at least one year prior to commencement of any construction. Two years of preconstruction baseline data would provide a stronger data base. Monitoring should proceed during all construction and could be terminated one to two years following startup provided no significant impacts were measured.

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APPENDIX 1

WATER & EFFLUENT QUALITY DATA

Columbia River above Birchbank

Fig. A1

Effluent Discharge & River Sample Station Locations

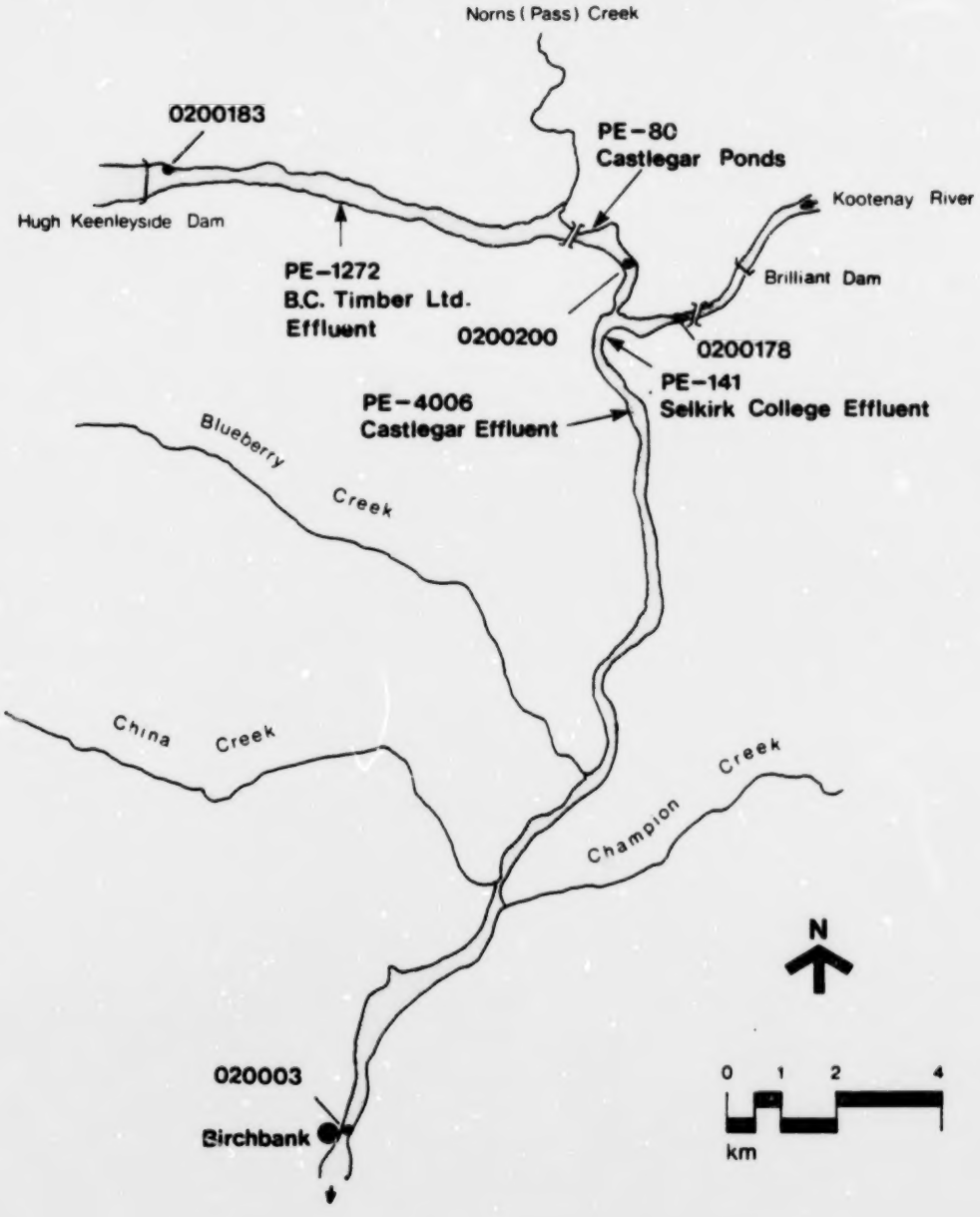

TABLE A 1.1

KOOTENAY RIVER WATER QUALITY - BRILLIANT DAM

1974 - 1979 (Station 0200178)

Date	pH	T.S. mg/L	T.D.S. mg/L	S.S. mg/L	Cond. us/cm	Temp. °C	D.O. mg/L	TURB. J.T.U.	Color	ALK. mg/L	TOC mg/L	Hard ness mg/L	NH_3 mg/L	NO_2 NO_3 mg/L	ORG. N. mg/L	TKN mg/L	Tot. N. mg/L	Ortho P. mg/L	Tot. Phos. mg/L	SO_4 mg/L	Tan. Lig. mg/L	Fec. Col. mg/L	Tot. Col. mg/L
13/2/7	7.85	100	98	-	180	3.5	13	0.65	-	69	2	76	<0.01	0.12	0.06	0.07	0.19	0.023	.029	12.9	<0.1	8	-
13/3	8	100	96	-	190	3.5	13	1.3	-	69	2	77.6	<0.01	0.12	0.02	0.03	0.15	0.024	.029	12.7	<0.1	79	-
22/4/7	8.2	98	96	-	156	-	13.3	0.8	-	67	<1	76.8	0.009	0.03	0.09	0.10	.13	<0.003	.020	-	0.1	-	-
18/6	8.4	82	78	-	130	12.5	-	0.9	-	55	3	61.4	0.009	<0.02	0.06	0.07	.07	<0.003	.016	12	0.2	-	-
21/7	8.4	72	70	-	100	16	11	0.5	-	45	2	54.1	0.013	<0.02	0.067	0.08	0.1	<0.003	.015	8.5	-	-	-
29/7	8	-	-	-	114	-	-	-	-	-	-	-	-	-	-	-	-	-	.003	-	-	-	-
18/9	8.3	72	70	-	101	-	9.6	1.5	-	50.8	1	56.6	0.010	<0.02	0.03	0.04	0.06	<.003	.010	9.7	-	-	-
5/11	7.9	82	-	-	90	9.8	-	-	1	58	-	65	0.012	0.02	0.09	0.10	0.12	-	.011	9.6	0.2	5	17
2/12	7.8	90	-	1	90	5	13.6	-	2	61	-	69.7	0.011	0.08	0.01	0.02	0.10	-	.016	11	0.1	2	5
6/1/76	7.7	94	-	1	90	3.8	14.4	-	3	68	-	78.6	0..10	0.13	0.06	0.07	.2	-	-	11.1	0.1	<2	5
29/1	8.2	94	92	-	164	4	11	0.5	-	68.4	-	79.2	0.012	0.13	0.088	0.10	0.23	.015	.002	12.4	-	-	-
3/2	7.8	102	-	1	92	3	13.8	-	2	68	-	76.7	0.006	0.13	0.08	0.09	0.22	-	.022	11.3	0.1	2	6
23/2	8.5	102	100	-	99	5	14	0.2	-	68.3	-	79.2	0.007	0.14	0.153	0.16	0.3	.015	.019	12	-	-	-
25/3	8.3	94	92	-	92	3.2	12.4	0.5	-	64.3	<1	72.5	0.010	0.11	0.16	0.17	0.28	.008	.017	11.3	-	-	-
6/4	8.4	100	98	-	104	7	14.2	0.6	-	66.6	2	74.5	<0.005	0.11	0.10	0.11	.22	.010	.019	11.8	-	-	-
21/4	8.5	90	-	2	100	6.5	-	-	2	-	-	70	0.006	0.09	0.11	0.12	.21	-	.011	10.5	<0.1	79	240
12/5	8.2	94	-	10	82	8	-	-	15	-	-	50.7	0.012	0.03	0.04	0.05	.08	-	.006	9.2	0.3	49	79
19/5	8	82	78	-	90	9.5	13.8	1.4	-	54	2	63	0.015	<0.02	0.15	0.16	.18	<.003	.018	10.2	-	<2	-
3/6	8.1	84	82	-	93	8.5	13.7	1.1	-	55	<1	64	0.006	0.04	0.14	0.15	.19	<.003	.016	9.3	-	8	-
22/7	8.65	74	-	6	95	16	-	-	<1	26.5	-	53.9	0.006	<0.02	0.20	0.21	0.21	-	.003	7.6	0.1	2	33
29/7	7.9	74	72	-	99	16	10.6	0.6	-	48.5	2	50.6	0.009	0.02	0.05	0.06	0.08	<.003	.010	8.5	-	2	-
16/8	8.5	76	-	4	100	15	-	-	5	33	-	55	0.011	-	0.09	0.10	.1	-	.003	8.8	0.1	2	49
18/8	7.9	72	70	-	95	16.8	10.6	0.6	-	42	3	53.2	0.011	0.02	0.08	0.09	.11	<.003	.009	8.7	-	2	-
21/9	8.1	92	-	3	105	15	10.1	0.6	-	55.3	<1	57.6	0.008	<0.02	0.10	0.11	.13	<.003	.009	8.4	-	<2	17
19/10	8.2	88	86	-	105	12	10.6	0.6	-	61.5	3	67.1	0.006	<0.02	0.04	0.05	.07	<.003	.006	10.4	-	7	79
24/11	8.2	90	88	-	99	7.5	11.6	0.5	-	61.2	<1	62.8	0.007	0.05	0.05	0.06	.11	<.003	.009	10	-	<2	11
21/12	7.6	98	94	-	101	4	11.5	0.5	-	65	2	70.9	0.006	0.09	0.04	0.05	.14	.009	.015	10.3	-	-	-
5/1/77	7.8	88	86	-	93	2.7	-	0.4	-	65.2	2	72	0.005	0.10	0.06	0.06	.16	.009	.013	10.4	-	<2	2
7/2	8	94	92	-	149	3	11.8	0.4	-	63.5	<1	69.9	<0.005	0.10	0.20	0.2	.3	.007	.012	10.3	-	<2	-
31/3	-	98	96	-	160	5	13.6	0.4	2	68.5	2	-	0.005	0.07	0.16	0.16	.23	.005	.014	-	0.1	<2	<2
26/5/77	8.6	94	92	-	141	8.5	12	1	4	61.3	1	-	0.012	<0.02	0.11	0.12	0.14	<.003	.014	-	0.2	2	5
16/6	8.5	76	74	-	131	12.5	11.4	1	7	56.7	3	67.2	0.007	0.06	0.11	0.12	0.18	<.003	.013	-	0.1	<2	8
11/7	7.8	76	74	-	128	15	9	0.6	<1	55.8	<1	-	0.010	<0.02	0.14	0.15	0.17	<.003	.012	-	0.1	<5	8
15/8	8.3	82	80	-	143	20.5	9.1	0.6	2	61.5	2	64.3	0.009	<0.02	0.08	0.09	0.11	<.003	.011	-	0.1	<2	49
19/9	8.3	94	92	-	149	14.7	9.5	0.5	2	64.2	<1	-	0.00[illegible]	<0.02	0.10	0.11	0.13	<.003	.010	-	0.1	2	79
5/10	8.2	88	86	-	146	12.2	10.5	0.6	3	64.9	2	-	0.005	<0.02	0.09	0.09	0.11	<.003	.010	-	0.1	5	79
14/11	8.1	92	90	-	159	7.2	10.8	0.5	3	69.7	1	76.8	0.007	0.02	0.06	0.07	0.09	<.003	.008	-	0.1	7	33
8/12	7.7	100	98	-	156	3	-	0.6	2	67	<1	-	<0.005	0.07	0.08	0.08	0.15	.004	.024	-	<0.1	-	-
9/1/78	7.7	98	96	-	164	3.6	12.9	0.5	6	70.2	1	-	0.005	0.10	0.01	0.01	0.11	.009	.014	-	0.1	<2	<2
7/2	8.1	102	100	-	157	2.8	12.2	0.5	2	68.6	<1	78.2	<0.005	0.11	0.10	0.10	0.21	.009	.013	-	0.2	<2	5
22/3	8.8	94	92	-	152	5.2	14.4	1.3	3	67.4	<1	-	<0.005	<0.02	0.07	0.07	0.09	<.003	.012	-	0.1	<2	<2
12/4	8	84	82	-	146	5.4	12.7	0.6	5	64	<1	-	<0.005	0.07	0.10	0.10	0.17	<.003	.014	-	0.1	<2	<2
11/5	8.3	82	78	-	137	7.2	12.9	0.9	5	61.4	2	-	0.007	<0.02	0.24	0.25	0.27	<.003	.016	-	0.1	<2	13
15/6	8.6	84	80	-	131	9	12.6	1.2	5	56.5	2	58.2	0.005	<0.02	0.18	0.18	0.2	<.003	.015	-	0.2	5	13
20/7	8.3	74	72	-	118	15.2	10.9	0.7	4	49.9	<1	-	0.004	<0.02	0.18	0.19	0.21	<.003	.008	-	0.1	2	540
9/8	8	74	72	-	124	19.8	11	0.5	7	52	1	58.7	0.004	<0.02	0.12	0.13	0.15	<.003	.009	-	0.1	2	-
16/10	8.0	80	78	-	135	10.3	11	0.6	<1	58	1	-	0.007	<0.02	0.05	0.06	0.08	<.003	.007	-	0.1	5	8
23/11	8.7	90	88	-	144	3.8	12.9	0.5	3	61.5	<1	59.2	0.005	0.04	0.08	0.08	0.12	<.003	.009	-	0.1	<2	2
15/1/79	8.1	102	100	-	164	1	-	0.8	4	69.5	<1	75.4	0.005	0.10	0.11	0.11	0.21	.006	.014	-	<0.1	<2	8
12/2	8	96	94	-	151	1.5	-	0.7	4	64.2	<1	63.7	0.010	0.11	0.07	0.08	0.19	.009	.011	-	<0.1	<2	8
22/3	8.3	108	106	-	164	4	13.9	0.8	2	70	2	-	0.009	<0.02	0.19	0.20	0.22	<.003	.014	-	0.2	2	8

TABLE A 1.2

COLUMBIA RIVER WATER QUALITY - HUGH KEENLEYSIDE DAM

1974 - 1979 (Station 0200183)

Date	pH	T.S.	T.D.S.	S.S.	Cond.	Temp.	D.O.	TURB.	Color	ALK.	TOC	Hardness	NH_3	NO_2 NO_3	ORG. N.	TKN	Tot. N.	Inorg. P.	Tot. Phos	SO_4	Tot. Lig.	Fec. Col.	Tot. Col
		mg/L	mg/L	mg/L	us/cm	°C	mg/L	J.T.U.	T.A.C.	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	MPN	MPN
13/3/74	7.95	78	76	-	160	3	12	1	-	59	1	62.7	<0.01	0.15	0.01	0.01	0.16	-	0.005	9.3	<0.01	-	-
17/3/75	8	88	84	-	142	3	12.6	1.1	-	60.5	<1	68.5	-	0.15	-	0.08	0.23	-	.010	-	<0.01	-	-
9/4	7.8	80	78	-	139	5	13	1	-	60	<1	66.7	-	0.14	-	0.02	0.16	-	.005	-	<0.01	-	-
15/5	8.3	86	84	-	139	8	11.6	-	-	59	1	67.2	-	0.12	-	0.23	0.35	-	.009	-	0.1	-	-
25/6	7.8	-	74	-	129	14.5	10.8	-	-	54	1	60.2	-	0.07	-	0.13	0.20	-	.009	-	0.2	-	-
15/7	8.2	94	80	-	129	16	11	0.8	-	55.1	<1	61.3	-	0.07	-	0.09	0.16	-	.017	-	0.2	-	-
4/9	7.95	54	52	-	85	17	10.6	0.4	-	36.6	3	41.9	-	0.08	-	0.13	0.21	-	.004	-	0.1	-	-
23/10	8.7	64	62	-	80	9.5	-	-	-	-	3	47	-	0.10	-	0.03	0.13	-	.004	-	0.1	-	-
5/11	7.7	72	-	-	80	9	-	-	1	56	-	57.9	.008	0.14	0.05	0.06	0.20	-	.005	7.6	0.1	<2	7
2/12	7.7	78	-	-	80	6.5	14.8	-	1	53	-	59.8	.005	0.13	<0.01	0.01	0.14	-	.005	8.6	0.1	<2	<2
6/1/76	8	74	-	-	78	5	15.8	-	2	59	-	60.3	.007	0.13	<0.01	0.01	0.14	-	.003	7.2	0.1	<2	<2
29/1	8.2	72	70	-	130	4	12.8	-	-	-	2	62.3	-	0.13	-	0.17	0.30	-	.003	-	0.1	-	-
3/2	7.7	90	-	-	76	4	14.5	-	2	58	-	61.2	.006	0.14	<0.01	<0.01	0.15	-	.004	8.4	0.1	<2	<2
23/2	8.6	74	-	-	78	4.5	12.6	-	-	-	-	61.3	-	0.14	-	0.11	0.25	-	.004	-	0.1	-	-
25/3	8.3	80	78	-	80	3	12.2	-	-	-	<1	62.3	-	0.14	-	0.03	0.17	-	.003	-	<0.1	-	-
6/4	8.3	78	72	-	80	5.4	12	-	-	-	<1	62	-	0.15	-	0.16	0.31	-	.003	-	0.1	-	-
21/4	8.2	76	74	-	85	6.5	-	-	2	-	-	61.2	<.005	0.14	0.06	0.06	0.20	-	.005	8.9	<0.1	-	-
12/5	7.8	80	-	-	88	10	-	-	3	-	-	61.7	.010	0.11	0.06	0.07	0.18	-	.011	8.7	0.2	<2	<2
19/5	7.8	78	76	-	90	13	12.5	-	-	51	3	60.9	-	0.11	-	0.09	0.20	-	.004	-	0.1	-	-
3/6	7.8	76	72	-	87	7.1	13.2	-	-	53	1	60.3	-	0.13	-	0.04	0.17	-	.004	-	0.2	-	-
22/7	8.2	86	-	-	80	15	-	-	<1	25	-	49.1	.008	0.13	0.03	0.04	0.17	-	.007	6.6	0.2	<2	49
25/7	7.7	66	62	-	92	16.5	10.6	-	-	40	3	44.6	-	0.14	-	0.06	0.20	-	.007	-	0.2	-	-
16/8	8.1	60	-	-	75	13.5	-	-	5	23	-	41.4	.009	0.14	0.13	0.14	0.28	-	.009	5.4	0.2	33	70
17/8	7.5	70	58	-	72	13	10.9	-	-	38	1	43	-	0.14	-	0.03	0.17	-	.026	-	0.2	5	540
21/9	8	68	64	-	92	15	10	-	-	45.8	<1	46.6	.005	0.08	0.085	0.09	0.17	-	.007	-	0.2	-	-
19/10	8	70	66	-	82	11.9	11.8	-	-	46.5	<1	51.3	-	0.08	-	0.01	0.09	-	.004	-	0.1	-	-
23/11	8	72	70	-	78	8	13	-	-	-	<1	49.7	-	0.11	-	0.03	0.14	-	.005	-	0.1	-	-
13/12	7.7	74	72	-	121	-	-	-	-	-	-	53.9	.007	0.13	0.04	0.05	0.18	-	.006	-	0.1	-	-
5/1/77	7.8	78	76	-	77	3	-	-	-	-	1	57.5	<.005	0.14	0.06	0.06	0.20	-	.006	-	<0.1	-	-
17/2	7.8	78	76	-	130	3.5	12	0.7	3	55.6	<1	-	<.005	0.16	0.05	0.05	0.21	-	.005	-	0.1	<2	5
31/3/77	8	84	80	-	131	5	12	0.5	1	56.5	2	-	<.005	0.15	0.04	0.04	0.19	-	0.003	-	<0.1	<2	<2
13/4	7.7	94	82	-	132	5	-	4.0	3	55.7	2	-	.005	0.18	<0.01	<0.01	0.19	-	.014	-	0.1	<2	<2
30/5	8.05	90	86	-	129	10	10.6	0.8	2	56.8	3	-	.005	0.11	0.05	0.05	0.16	-	.008	-	0.1	<2	8
15/6	8.4	106	74	-	127	10	11	1.5	6	55.6	5	-	.007	0.11	0.13	0.14	0.25	-	.025	-	0.2	-	-
27/7	7.9	66	64	-	99	16	-	0.6	3	51.5	3	56	.006	0.15	0.10	0.11	0.26	-	.005	-	0.1	<2	<2
10/8	7.7	64	62	-	106	20.6	8.1	0.6	<1	45.8	<1	50.6	.008	0.11	0.07	0.08	0.19	-	.005	-	0.1	-	-
12/9	8.3	66	64	-	109	15	9.8	0.6	<1	47.1	<1	49.6	<.005	0.08	0.02	0.02	0.10	-	.003	-	0.1	<2	<2
4/10	8	70	68	-	110	11.8	10.1	0.4	2	48.9	<1	-	<.005	0.09	0.03	0.03	0.12	-	.004	-	0.1	<2	8
16/10	7.6	64	-	-	116	12	-	0.4	2	49.9	1	53.4	<.005	0.09	0.06	0.06	0.15	-	.005	7.4	0.1	<2	2
1/11	7.5	78	74	-	121	8.1	9.9	0.7	<1	52.8	<1	53.6	<.005	0.13	0.08	0.08	0.21	-	.006	-	0.1	<2	7
1/12	7.7	78	76	-	125	4.3	10.7	0.8	3	50	<1	-	.009	0.14	0.04	0.05	0.19	-	.005	-	<0.1	<2	2
5/1/78	7.7	74	72	-	127	1.5	-	-	2	-	-	-	-	-	-	-	-	-	.004	-	0.1	<2	<2
2/2	7.6	80	76	-	129	0.3	12.4	1.2	1	61	<1	63.2	.005	0.15	0.10	0.10	0.25	-	.012	-	0.1	<2	5
7/3	7.7	88	84	-	134	2.8	12.3	0.8	4	60	<1	-	-	0.15	0.12	0.12	0.27	-	.005	-	<0.1	<2	<2
11/4	7.7	90	88	-	136	6.5	11.8	1.0	2	58	<1	-	-	0.14	0.07	0.07	0.21	-	.005	-	0.1	<2	2
2/5	7.6	86	80	-	131	6.3	11.4	2.2	4	57	<1	-	-	0.13	0.08	0.08	0.21	-	.008	-	0.1	<2	2
6/6	7.9	76	74	-	124	11.8	13.2	0.5	5	53	2	59.2	-	0.09	0.07	0.07	0.16	-	.007	-	0.2	2	5
12/7	7.9	82	66	-	115	15.2	11	1.2	7	45	2	-	0.01	0.04	0.10	0.11	0.15	-	.014	-	0.2	<2	17
3/8	7.9	70	66	-	107	15.2	10.9	0.6	3	45	<1	49.7	.02	0.12	0.05	0.07	0.19	-	.008	-	0.2	<2	11
16/8	8	-	-	-	106	-	-	-	3	44.9	-	-	-	-	-	-	-	-	-	-	-	-	-
12/9	7.7	60	58	-	96	13.1	11	0.5	1	37	1	-	-	0.11	0.10	0.10	0.21	-	.006	-	0.1	<2	2
11/10	7.7	66	64	-	103	10.8	11	0.5	<1	42	<1	-	-	0.09	0.04	0.04	0.13	-	.005	-	0.1	<2	<2
9/11	7.7	72	70	-	115	6.2	12.2	3.4	3	48	2	51.1	-	0.12	0.08	0.08	0.20	-	.005	-	<0.1	<2	<2
3/1/70	8.1	86	78	-	129	-	13.5	1.8	1	55.8	<1	-	-	0.15	0.08	0.08	0.23	-	.010	-	0.1	<2	2
6/2	7.9	76	74	-	134	-	-	0.8	1	57.7	<1	46.8	-	0.15	0.05	0.05	0.20	-	.006	-	<0.1	<2	<2
15/3	8.1	80	78	-	139	2.8	-	1.1	<1	60.9	<1	-	-	0.15	0.01	0.01	0.16	-	.005	-	0.1	<2	<2
10/4	7.8	82	80	-	139	2.8	13	0.5	2	60.8	<1	-	-	0.14	0.06	0.06	0.20	-	.004	-	<0.1	<2	<2

TABLE A 1.3
COLUMBIA RIVER WATER QUALITY - CASTLEGAR
1974 - 1979 (Station 0200200)

Date	pH	T.S. mg/L	T.D.S. mg/L	S.S. mg/L	Cond. uS/cm	Temp. °C	D.O. mg/L	Turb. J.T.U.	Color T.A.C.	Alk. mg/L	TOC mg/L	Hard ness mg/L	N_2 mg/L	NO_2 NO_3 mg/L	ORG N. mg/L	TKN mg/L	Tot. N. mg/L	Tot. Phos. mg/L	SO_4 mg/L	Tan. Lig. mg/L	Fec. Col. MPN	Tot. Col. MPN	cfs
25/6/75	7.4	84	82	-	127	12.5	9.8	1.7	-	51	4	57.1	-	0.05	-	0.23	0.28	.023	-	0.8	-	-	5230
15/7	8	94	92	-	141	17.5	8.2	0.15	-	55.4	3	61.8	-	0.05	-	0.19	0.24	.019	-	1.2	-	-	5443
4/9	8	54	52	-	86	17.3	10.7	1.7	-	36.7	2	40.9	-	0.09	-	0.11	0.20	.304	-	0.2	-	-	38200
23/10	8.7	74	72	-	80	9	-	-	-	-	2	51	-	0.14	-	0.09	0.23	.308	-	0.8	-	-	7060
2/12	7.7	76	-	1	80	6.5	15.8	-	3	53	-	59.8	.306	0.12	0.01	0.02	-	.306	8.6	0.3	20	20	45530
6/1/76	8.1	76	-	1	78	5	14.4	-	5	56	-	60.3	.308	0.12	0.10	0.11	0.23	.305	9.2	0.4	<2	5	19900
29/1	8.1	80	78	-	132	4.5	11.6	-	-	-	4	62.3	-	0.14	-	0.18	0.32	.305	-	0.2	-	-	42600
3/2	8	80	-	1	79	4	14.5	-	4	58	-	61.1	.306	0.14	0.12	0.13	-	.304	8.4	0.3	<2	4	33500
23/2	9.9	78	-	1	78	5.5	14.4	-	-	-	-	61.7	-	0.04	-	0.08	0.12	.306	-	0.5	-	-	23200
25/3	8	82	80	-	80	3	11.8	-	-	-	<1	62.2	-	0.14	-	0.04	0.18	.304	-	0.2	-	-	49600
6/4	8.2	82	80	-	85	6.5	12.2	-	-	-	<1	62.2	-	0.14	-	0.18	0.32	.305	-	0.3	-	-	43100
21/4	8.3	80	78	-	85	7	-	-	<1	-	-	60	.310	0.13	0.11	0.12	0.25	.305	8.5	<0.1	<2	<2	7920
12/5	7.6	78	-	2	90	9.5	-	-	3	-	-	60.8	.310	0.11	<0.01	0.01	0.12	.307	9.2	0.3	2	5	42900
19/5	7.8	82	78	-	95	11.5	12.4	-	-	49	2	61.8	-	0.11	-	0.13	0.24	.305	-	0.4	-	-	30630
3/6	7.9	86	84	-	90	7.5	13.9	-	-	53	<1	61	-	0.10	-	0.18	0.28	.307	-	0.5	-	-	20300
22/7	8.2	54	-	1	82	15	-	-	1	25.5	-	46.7	.308	0.12	0.09	0.10	0.22	.307	6.6	0.2	2	21	83400
26/7	7.5	64	62	-	85	16.5	11.2	-	-	42	3	45.3	-	0.15	-	0.07	0.22	.311	-	0.3	-	-	97700
16/8	7.9	60	-	2	75	13.8	-	-	4	24.5	-	39.4	.308	0.14	0.11	0.12	0.26	.307	5.9	0.2	4	33	103000
17/8	7.8	64	62	-	75	13.5	11.6	-	-	38	1	42.5	-	0.14	-	0.14	0.28	.306	-	0.3	8	79	133000
21/9	8	58	-	2	85	14.9	10.5	-	-	46	<1	47.1	.305	0.08	-	0.07	-	.308	-	0.3	-	-	60600
19/10	8	74	72	-	85	12	11.8	-	-	46.5	<1	53.4	-	0.07	-	0.01	0.08	.304	-	0.2	-	-	44800
23/11	8.3	76	74	-	80	7.9	13	-	-	-	<1	50	-	0.09	-	0.02	0.11	.305	-	0.3	-	-	29200
13/12	8	74	72	-	121	-	-	-	-	-	-	54.4	.307	0.13	0.08	0.07	-	.305	-	0.2	-	-	57200
6/1/77	7.8	80	78	-	79	3.5	-	-	-	-	2	58.5	.305	0.13	0.05	0.05	-	.306	-	0.3	-	-	43600
17/2	7.9	88	86	2	131	3.5	12.2	0.7	4	55.5	<1	-	<.305	0.15	0.07	0.07	-	.305	-	0.2	<2	7	33100
31/3	8.2	82	80	2	134	5	12	0.6	2	56.9	1	-	<.305	0.15	0.07	0.07	-	.305	-	0.3	<2	<2	30800
13/4	8	78	76	2	132	6	-	0.8	3	58	1	-	<.305	0.15	<0.01	<0.01	-	.305	-	0.2	<2	5	4420
30/5	8.05	82	80	2	130	10	10.5	0.6	3	56.6	3	-	.308	0.12	0.04	0.05	-	.308	-	0.3	<2	14	74500
15/6	9.1	86	84	2	129	10	11.8	0.6	9	56.2	4	-	<.305	0.10	0.12	0.12	-	.307	-	0.4	-	-	30300
27/7	7.6	72	68	3	99	22.5	-	0.7	5	51.5	3	56	<.305	0.15	0.08	0.08	-	.308	-	0.3	8	33	62000
10/8/77	7.75	72	70	2	108	21.2	9.3	0.6	<1	47.1	<1	50.3	<.005	0.10	0.08	0.08	-	.307	-	0.2	<2	8	55600
12/9	8.2	64	62	2	112	16	9.6	0.6	1	47.3	<1	49.8	<.005	0.08	0.07	0.07	-	.304	-	0.2	<2	13	46800
4/10	7.9	70	68	<1	114	12.6	10.3	0.6	6	48.8	2	-	.005	0.09	<0.01	<0.01	-	.307	-	0.3	2	23	27100
16/10	7.5	70	-	<1	119	12	-	0.5	6	49.7	1	53.3	.307	0.08	0.05	0.05	0.14	.306	7.4	0.4	<2	4	17300
1/11	7.5	74	72	2	122	7.8	10.1	0.7	2	53.6	<1	54.9	.305	0.13	0.04	0.04	-	.305	-	0.7	<2	17	31200
1/12	7.3	76	74	1	126	3.8	10.9	0.6	4	48	<1	-	<.005	0.13	<0.01	<0.01	-	.307	-	0.3	<2	11	33000
5/1/78	7.7	78	76	2	128	-	-	-	5	-	-	-	-	-	-	-	-	.306	-	0.4	<2	14	21200
2/2	7.5	82	80	1	133	0.8	13	0.6	6	62	<1	62.9	<.305	0.13	0.11	0.11	-	.007	-	0.5	2	17	14000
7/3	7.8	86	84	2	135	3.1	12.3	0.6	2	60	<1	-	<.305	0.14	0.12	0.12	-	.305	-	0.2	<2	<2	44300
11/4	8	100	98	2	149	7.8	12.9	2.1	19	59	4	-	<.310	0.09	0.14	0.14	-	.308	-	1.1	<2	23	5050
2/5	7.7	82	80	1	133	7.9	11.2	0.6	7	56	<1	-	<.005	0.12	0.15	0.15	-	.007	-	0.2	<2	8	28300
6/6	8.3	76	72	4	124	13.6	13.9	1.0	11	49	3	55.4	<.305	0.06	0.18	0.18	-	.010	-	0.5	<2	23	10200
12/7	7.7	76	72	4	121	16	11.2	0.6	10	48	2	-	.013	0.05	0.02	0.03	-	.007	-	0.5	8	33	35600
3/8	7.7	66	64	2	109	17.2	10.8	0.5	5	45	<1	50.2	.008	0.11	0.08	0.09	-	.009	-	0.3	7	130	46800
12/9	7.7	64	62	1	97	13.4	11.1	0.3	1	38	1	-	<.005	0.10	0.09	0.09	-	.006	-	0.1	<2	7	70100
11/10	7.7	70	68	2	107	11.1	11.6	0.6	4	42	<1	-	<.005	0.09	0.10	0.10	-	.008	-	0.3	2	2	32000
9/11	7.5	72	70	1	119	6.1	12	0.5	5	47	2	52.4	<.305	0.12	0.06	0.06	-	.006	-	0.2	<2	8	40900
3/1/79	8.1	86	84	<1	132	0	14	0.7	3	55.9	1	-	.005	0.15	<0.01	<0.01	-	.006	-	0.2	<2	<2	-
6/2	7.9	82	80	1	136	-	-	0.8	7	57.5	<1	49.8	<.005	0.15	0.13	0.13	-	.008	-	0.2	<2	5	-
15/3	8.1	86	84	2	141	2.5	-	1.1	3	60.8	1	-	<.005	0.14	0.05	0.05	-	.007	-	0.3	<2	2	-
10/4	7.8	88	86	1	144	3.2	13.4	0.8	6	61.2	<1	-	<.005	0.13	0.09	0.09	-	.007	-	0.2	<2	2	-

TABLE A 1.9

COLUMBIA RIVER WATER QUALITY - RINCHBANK

1976 - 1979 (Station 0200003)

Date	pH	T.S.	T.D.S.	S.S.	Cond.	Temp.	D.O.	TURB	Color	ALK.	TOC	Hard ness	NH_3	NO_2 NO_3	ORG. N.	TKN	Tot. N.	Ortho P.	Tot. Phos.	SO_4	Tox Lig.	Fec. Col.	Tot Col.
		mg/L	mg/L	mg/L	us/cm	°C	mg/L	J.T.U.	T.A.C.	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	MPN	MPN
8/1/73	7.8	88	-	7.5	140	1.0	14.4	1	-	59	1	68.1	<0.01	0.15	0.06	0.07	0.22	0.004	0.012	12	<0.1	8	240
12/2	7.8	90	-	<1.0	140	4	10.6	1	-	61	3	69.7	<0.01	0.15	0.09	0.1	0.25	0.011	0.019	11.6	0.1	33	-
15/3	7.8	96	-	2	155	4	11.4	1.7	-	62	5	68.1	0.01	0.11	0.07	0.08	0.19	0.011	0.014	12	0.5	2	-
5/4	7.4	86	-	2	150	6	12	1.6	-	59	4	66.4	<0.01	0.15	0.12	0.13	0.28	<0.003	0.012	11	0.1	2	-
15/5	7.7	84	80	3.7	180	8.5	-	1.2	-	56.7	3	60.6	0.07	0.07	0.15	0.22	0.29	<0.003	0.017	9	0.2	5	-
28/5	7.5	82	74	-	125	14	10.8	1.5	-	54	4	57.3	<0.01	0.08	0.14	0.15	0.23	<0.003	0.014	10	0.1	2	-
18/7	7.6	76	72	-	125	16	9.6	2	-	54	4	53.6	<0.01	0.13	0.17	0.18	0.31	<0.003	0.012	10	0.2	7	-
20/8	7.8	72	68	-	-	16	-	1.9	-	54.6	4	55.6	0.2	0.09	0.10	0.11	0.2	<0.003	0.008	8	<0.1	-	-
25/10	8.0	84	82	-	130	10	10.1	1.1	-	55	4	59.4	-	0.07	-	0.06	0.13	<0.003	0.011	8	0.2	79	-
6/11	7.95	82	80	-	148	6	12.2	0.8	-	58	1	64.3	<0.01	0.07	0.05	0.06	0.13	<0.003	0.008	10	<0.1	33	-
29/11	8.15	92	84	-	162	4.5	12.3	0.99	-	62	1	68.1	0.01	0.08	0.04	0.05	0.13	0.006	0.014	11.5	0.2	2	-
13/2/74	7.75	96	94	-	180	3	13	0.85	-	53	2	74	<0.01	0.13	0.02	0.03	0.16	0.021	0.027	13.3	0.2	9	-
13/3	8.0	88	86	-	178	3.5	13	0.9	-	64	2	70.4	0.04	0.14	0.03	0.07	0.21	0.011	0.020	11.2	<0.1	17	-
17/3/75	8.0	98	86	-	149	-	-	0.7	-	62	<1	70.2	-	0.12	-	0.10	0.22	0.008	0.018	-	0.2	-	-
9/4	8.0	98	86	-	146	5	14	1.5	-	64	<1	70	-	0.12	-	<0.01	0.12	<0.003	0.012	-	0.2	-	-
15/5	8.2	88	84	-	137	7	13.2	-	-	56.5	1	65.1	-	<0.02	-	0.11	0.11	<0.003	0.024	-	0.3	-	-
25/6	7.8	68	66	-	119	12	10.5	3.7	-	47	1	55.5	-	<0.02	-	0.16	0.16	<0.003	0.022	-	0.3	-	-
15/7	8.2	74	72	-	126	16.5	10.2	0.95	-	47.7	1	53.5	-	<0.02	-	0.12	0.12	<0.003	0.014	-	0.2	-	-
6/8	7.9	66	64	-	111	18	10	0.5	-	46.1	3	51.3	-	0.07	-	0.03	0.096	<0.003	0.007	-	0.2	-	-
4/9	8.15	60	58	-	93	16.5	9.9	0.4	-	39.4	2	43.9	-	0.06	-	0.12	0.18	<0.003	0.006	-	0.2	-	-
23/10	8.4	76	74	-	85	9.5	-	-	-	-	-	58	-	0.03	-	0.06	0.09	<0.003	0.007	-	0.3	-	-
5/11	7.7	76	74	-	85	9.5	-	-	<1	56	-	60.2	0.01	0.08	0.04	0.05	0.13	<0.003	0.008	9.6	0.2	8	33
2/12	7.7	78	76	-	90	6	14.8	-	3	55	-	63.5	0.01	0.10	0.05	0.06	0.16	<0.003	0.010	9.5	0.2	2	7
6/1/76	8.2	90	88	-	90	4.5	15	-	4	64	-	72.3	0.01	0.13	0.11	0.12	0.25	<0.003	0.016	9.7	0.2	<2	13
22/1	7.8	84	-	1.0	147	-	-	0.4	-	61.2	-	69.5	0.01	0.14	0.21	0.22	0.36	0.008	0.011	-	0.2	<23	<23
3/2	8.0	84	82	-	85	3.5	14	-	3	52	-	59.5	0.01	0.14	0.06	0.07	0.21	-	0.013	10.4	0.2	4	17
24/2	8.4	92	90	-	151	4	12	0.5	-	63	-	67.1	<0.005	0.12	0.07	0.07	0.19	0.010	0.015	-	0.2	-	-
16/3	8.0	98	-	1.0	143	5	-	0.7	-	-	-	67.9	<0.005	0.12	0.07	0.07	0.19	0.006	0.010	-	0.4	-	-
12/4	8.4	94	-	2.0	145	7	12.1	1.3	-	60.7	-	66.7	0.01	0.09	0.10	0.11	0.2	0.007	0.017	-	0.1	-	-
12/5	7.9	92	76	-	80	8.5	-	-	7	-	-	58.4	0.01	0.06	<0.01	<0.01	0.06	-	0.018	8.7	0.2	49	49
22/7	8.3	68	66	-	90	15.5	-	-	<1	25	-	51.3	0.01	0.09	0.07	0.08	0.17	-	0.012	7.1	0.2	<2	23
26/7	7.7	56	-	4	92	17.4	11	0.9	-	42	-	47.9	0.02	0.09	0.05	0.07	0.16	0.003	0.010	-	0.3	-	-
16/8	8.2	66	64	-	95	14.7	-	-	-	25.5	-	45.5	0.009	0.09	0.48	0.49	0.58	-	0.006	7.8	0.2	<2	23
21/9	8.0	74	-	2	95	14.5	11	0.5	-	50	-	50.9	0.005	0.05	0.08	0.09	0.14	<0.003	0.008	-	0.2	-	-
19/10	7.9	78	-	2	92	8.8	11.2	0.4	-	51.5	-	56.9	0.006	0.05	0.02	0.03	0.08	<0.003	0.004	-	0.2	-	-
23/11	8.0	76	74	-	87	6.2	12	0.5	-	-	-	56.3	0.007	0.08	0.03	0.04	0.12	<0.003	0.006	-	0.2	-	-
13/12	8.0	82	-	2	131	-	-	0.5	-	-	-	55.5	0.007	0.12	0.03	0.04	0.16	<0.003	0.006	-	0.1	-	-
12/1/77	7.6	90	-	2	131	-	-	0.5	-	53	-	59.8	<0.001	-	-	-	-	<0.003	-	-	-	-	-
17/2	7.9	88	86	1	137	4	-	0.6	3	58.5	1	64.6	<0.005	0.14	0.06	0.06	0.20	0.004	0.007	-	0.1	-	5
30/3	7.8	86	84	1	143	5	12.3	0.5	11	61.6	2	65.1	<0.005	0.11	0.25	0.25	0.36	0.003	0.007	-	0.2	-	11
13/4	8.3	96	94	2	147	6.5	-	0.5	2	64.9	1	66.1	0.01	0.09	0.06	0.07	0.16	<0.003	0.009	-	0.1	-	2
30/5	8.2	82	80	3	133	10	10.9	0.6	3	58.4	2	64.7	0.01	0.09	0.06	0.07	0.16	<0.003	0.010	-	0.2	-	2
15/6	8.4	88	80	3	127	10	11.5	0.9	7	55.2	2	56.8	<0.005	0.05	0.15	0.15	0.2	<0.003	0.010	-	0.2	-	-
27/7	7.95	70	68	3	100	22	-	0.6	3	54.5	4	58.8	0.01	0.11	0.13	0.14	0.25	<0.003	0.008	-	0.2	-	11
10/8	7.58	70	68	2	117	21	-	0.8	1	50.7	<1	54.9	0.01	0.09	0.09	0.10	0.19	<0.003	0.009	-	0.1	-	-
6/9	8.2	74	72	<1	63.6	-	-	0.6	<1	52.3	<1	54.2	0.01	0.08	0.03	0.04	0.12	<0.003	0.005	-	0.1	-	2
12/9	8.2	70	68	2	122	15	9.6	0.6	<1	52.2	<1	55.1	<0.005	0.06	0.13	0.13	0.19	<0.003	0.007	-	0.2	-	33
4/10	8.1	80	78	<1	127	11.5	10.1	0.6	3	55.6	2	62.2	0.005	0.06	0.08	0.08	0.14	<0.003	0.006	-	0.2	-	70
1/11	7.3	80	78	2	134	8.2	10.1	0.6	2	57.8	<1	60.4	<0.005	0.09	0.08	0.08	0.17	<0.003	0.006	-	0.2	-	33
1/12	7.5	92	90	1	139	4.5	10.7	0.6	2	54	1	63.1	<0.005	0.10	<0.01	<0.01	0.11	<0.003	0.007	-	0.2	-	13
5/1/78	7.9	88	86	<1	150	1	12.4	-	7	29	-	69.6	<0.001	-	-	-	-	<0.003	-	-	-	-	-
2/2	7.8	96	94	1	153	1.3	13.3	0.6	2	74	<1	74.8	<0.005	0.12	0.09	0.09	0.21	0.007	0.013	-	0.3	-	23
7/3	7.8	84	82	2	140	3.2	12.6	0.6	3	63	<1	70.5	<0.005	0.11	0.10	0.10	0.21	<0.003	0.006	-	0.1	-	2
11/4	7.8	80	78	3	146	6.6	11.6	0.7	4	63	<1	70.8	<0.005	0.07	0.11	0.11	0.18	<0.003	0.012	-	0.2	-	13
2/5	8.0	96	82	4	130	8.1	11.9	0.8	6	56	<1	61.4	<0.005	0.07	0.17	0.17	0.24	<0.003	0.008	-	0.2	-	33
5/6	8.0	84	74	11	119	12.4	11.2	2.4	7	50	<1	55.0	<0.007	0.04	0.05	0.06	0.1	<0.003	0.016	-	0.3	-	17
11/7	7.7	70	66	4	115	14.8	10.9	0.8	8	46	<1	54 9	<0.005	<0.02	0.17	0.17	0.19	<0.003	0.010	-	0.3	-	23
2/8	8.0	70	68	2	116	19.5	10.2	0.5	4	47	2	52.1	0.01	0.06	0.08	0.09	0.15	<0.003	0.009	-	0.2	-	229
11/9	7.9	54	52	2	108	13.8	11.8	0.4	1	44	1	48.9	<0.005	0.08	0.10	0.10	0.18	<0.003	0.006	-	0.1	-	4
10/10	7.8	70	68	1	118	12.1	11	0.4	2	47	<1	53.4	0.009	0.05	0.01	0.02	0.07	<0.003	0.007	-	0.2	-	140
9/11	7.7	74	72	1	128	7.5	12.4	0.5	5	52	<1	58.4	<0.005	0.08	0.08	0.08	0.16	<0.003	0.005	-	0.1	-	5
3/1/79	8.2	90	78	<1	141	0	14	0.6	2	59.6	<1	64.7	<0.005	0.14	0.17	0.17	0.31	<0.003	0.007	-	0.1	-	13
14/3/79	8.0	98	96	2	148	2.9	13.6	1.2	3	63.5	<1	61.2	0.01	0.09	0.12	0.13	3.22	<0.003	0.009	-	0.3	-	2
9/4	8.1	86	84	1	145	3.8	12.5	0.7	2	63	<1	61.3	<0.005	0.10	0.08	0.08	0.18	<0.003	0.008	-	0.1	-	<2

TABLE A 1.5

BC TIMBER LTD. EFFLUENT DATA 1974 - 1979

DATE	COLOUR	pH	T.S. mg/L	S.S. kg/ADT	V.S.S. mg/L	D.O. mg/L	BOD_5 kg/ADT	PROD. Tonnes/day
13/11/73	1600	3.3	1280	19.45	70	1.5	38.5	606
20/11/73	1550	6.0	1344	21.4	81	3.4	55.5	564
27/11/73	1600	5.7	1489	36.8	26	3.6	42.5	522
04/12/73	1720	6.3	1161	28.0	25	2.2	34.5	503
11/12/73	1560	3.0	1461	38.0	168	4.2	35.0	603
18/12/73	1400	6.3	1331	24.0	25	2.8	24.0	580
03/01/74	1400	5.7	1808	12.5	100	-	36.5	-
08/01/74	1800	-	1650	48.5	202	-	40.0	-
15/01/74	1850	-	1573	55.0	246	-	-	-
05/02/79	1400	5.3	1547	14.5	78	1.5	42.5	635
12/02/74	1400	3.7	1387	15.5	112	1.6	33.5	566
19/02/74	1250	6.0	1288	35.5	176	2.0	35.5	558
26/02/74	1150	-	1237	21.0	118	2.7	35.5	552
05/03/74	1250	8.7	1440	68.0	184	1.9	46.0	491
12/03/74	1300	6.7	1529	20.0	81	0	41.0	542
19/03/74	1250	6.5	1171	32.5	168	1.5	41.5	498
26/03/74	1500	5.4	1479	27.5	162	1.4	40.0	613
02/04/74	1200	6.7	1084	36.0	114	2.9	51.5	-
10/04/74	1400	3.6	1404	13.0	96	0.6	39.5	-
23/04/74	1400	7.2	1720	101.0	158	0.5	36.5	-
30/04/74	2000	6.1	1369	7.0	76	0	28.5	-
07/05/74	1140	4.6	1047	17.0	128	1.8	29.5	-
14/05/74	2000	5.9	1208	28.5	169	1.8	32.0	-
21/05/74	1160	4.1	1228	26.5	174	3.1	26.5	-
28/05/74	3200	7.0	1878	26.5	180	0	82.5	-
04/06/74	1100	3.9	1183	47.0	72	1.9	29.0	498
11/06/74	1000	3.6	1190	6.5	115	4.1	32.0	567
18/06/74	940	4.0	1178	7.0	88	1.8	33.5	590
25/06/74	1240	3.2	1181	4.0	96	1.8	34.0	612
03/07/74	1050	6.0	1458	17.8	92	2.3	38.5	493

TABLE A 1.5

BC TIMBER LTD. EFFLUENT DATA 1974 - 1979 (CONTINUED)

DATE	COLOUR	pH	T.S. mg/L	S.S. kg/ADT	V.S.S. mg/L	D.O. mg/L	BOD_5 kg/ADT	PROD. Tonnes/day
23/07/74	1020	5.2	1440	11.4	20	1.1	34.5	603
06/08/74	1280	6.7	985	34.0	125	0.3	30.5	445
20/08/74	1200	3.6	1090	21.0	89	4.1	23.0	520
28/08/74	1150	4.5	1066	20.0	60	2.0	30.5	548
10/09/74	1020	8.6	918	108.5	110	4.0	55.0	242
17/09/74	1060	6.2	925	15.0	94	4.1	30.0	562
24/09/74	1280	-	1131	31.0	86	3.1	32.0	544
02/10/74	400	11.3	830	11.0	62	-	20.5	511
16/10/74	1280	6.4	1290	35.5	140	2.1	40.5	499
22/10/74	800	5.3	999	10.5	79	3.3	24.5	607
29/10/74	1280	6.4	1246	37.5	170	0	37.5	489
05/11/74	1060	3.8	1264	26.0	141	3.1	37.5	592
12/11/74	1060	3.0	1047	27.5	107	3.0	45.0	449
26/11/74	1300	5.5	1165	14.5	102	3.8	32.0	410
10/12/74	1060	5.6	1247	8.5	68	4.1	30.5	479
17/12/74	1200	3.5	1152	10.4	86	3.7	30.0	589
30/12/74	1800	-	1528	34.1	116	-	50.0	409
07/01/75	1300	-	1425	23.2	260	4.8	49.5	267
14/01/75	1200	-	1100	18.5	72	2.9	27.0	576
02/11/75	1400	3.0	1280	8.5	68	2.2	33.5	504
28/01/75	1600	8.0	1496	151.5	202	1.6	68.5	229
04/02/75	1700	7.5	2031	136.0	242	1.2	-	578
11/02/75	2000	-	1852	106.5	196	3.1	38.0	532
18/02/75	1600	4.2	1284	7.5	75	3.1	44.5	486
25/02/75	1400	3.5	1253	20.5	108	3.0	33.5	529
04/03/75	1940	6.0	1667	17.0	88	1.5	57.5	477
10/03/75	2000	6.8	1546	-	-	2.5	-	508
11/03/75	1560	4.8	1342	19.5	92	2.6	34.5	469
18/03/75	1940	4.5	1578	19.0	68	1.5	54.5	559
26/03/75	340	4.5	1311	9.0	84	5.4	43.0	580

TABLE A 1.5

BC TIMBER LTD. EFFLUENT DATA 1974 - 1979 (CONTINUED)

DATE	COLOUR	pH	T.S. mg/L	S.S. kg/ADT	V.S.S. mg/L	D.O. mg/L	FLOW m^3/day	BOD_5 kg/ADT	PROD. Tonnes/day
08/05/76	1900	-	1339	27.0	100	4.8	-	46.5	457
15/04/76	1800	6.5	1419	20.5	80	3.0	-	46	558
23/04/76	1120	5.0	1720	12.0	70	0.9	-	50.5	561
01/05/76	1560	5.4	1277	7.1	78	0	-	42.5	524
07/03/76	1800	7.0	1247	14.4	86	1.1	-	39.5	468
14/05/76	1900	7.5	1453	22.1	88	0.1	-	48.5	527
20/05/76	1060	3.5	1098	23.9	67	0	-	31	537
29/05/76	2000	6.3	1340	-	-	1.7	-	-	478
03/06/76	1700	5.3	1218	11.5	70	2.3	-	41.5	533
10/06/76	1160	-	1185	14.0	60	2.3	-	35	455
17/06/76	1200	5.0	1608	21.5	96	0	-	51.5	560
24/06/76	1800	5.5	1230	54.0	228	4.6	-	50.5	398
26/06/76	2000	7.9	1142	-	-	0	-	-	533
08/07/76	1760	6.8	1780	16.5	44	0	-	60.5	515
09/07/76	4000	7.0	B	-	-	4.5	-	-	566
21/10/76	-	6.0	1267	-	-	11.2	130970	50	507
04/11/76	-	4.8	1430	18.0	62	0	125670	46	592
11/11/76	-	6.0	1524	25.0	80	-	127190	52.5	547
18/11/76	1300	8.8	1121	55.0	96	0	126810	121.5	219
25/11/76	1000	-	1070	26.0	92	0.7	127560	35	529
27/11/76	800	2.8	F	-	-	1.9	130970	-	562
02/12/76	1200	3.7	981	28.0	79	1.4	124920	43	410
10/12/76	1800	4.0	1249	38.5	140	4.5	135140	53	486
16/12/76	800	-	1014	16.0	90	3.5	119990	35	553
23/12/76	1200	-	1159	17.5	62	2.2	123780	52	464
06/01/76	840	5.0	991	41.0	126	-	129840	35.5	447
13/01/76	660	6.5	839	74.0	184	7.7	126050	-	308
20/01/76	1260	5.0	1085	37.0	114	0	127190	38.5	432
27/01/76	2000	7.2	1914	45.0	134	0	125670	59.5	527

TABLE A 1.5

BC TIMBER LTD. EFFLUENT DATA 1974 - 1979 (CONTINUED)

DATE	COLOUR	pH	T.S. mg/L	S.S. kg/ADT	V.S.S. mg/L	D.O. mg/L	FLOW m^3/day	BOD_5 kg/ADT	PROD. Tonnes/day
28/01/76	1000	7.3	1394	-	-	2.5	126430	-	478
03/02/76	1600	5.6	1262	17.5	68	3.2	126050	60.5	421
10/02/76	1120	6.0	1322	28.0	126	3.6	131730	38.0	594
17/02/76	800	4.5	1218	23.0	78	2.4	130210	48.5	449
24/02/76	1800	7.0	1579	58.5	154	1.6	138920	50.0	565
25/02/76	1000	5.8	1708	-	-	2.1	128700	-	567
02/03/76	1900	5.8	1660	52.5	120	4.6	125470	43.0	515
09/03/76	1800	8.0	1996	65.5	142	0	126830	55.0	566
17/03/76	1100	7.3	1358	93.0	200	2.7	127740	42.0	442
23/03/76	1600	5.0	1237	21.5	98	0.6	123200	38.0	489
30/03/76	1400	5.5	1481	29.0	-	0.9	122290	41.0	578
31/03/76	2000	6.0	1862	-	-	1.3	122740	-	410
06/04/76	2000	6.5	1721	67.5	124	0.4	125470	40.0	557
27/04/76	1280	3.6	1125	26.5	132	3.0	135920	29.0	449
04/05/76	800	5.5	1084	12.0	64	5.2	152290	23.0	544
11/05/76	1200	6.0	1340	48.5	136	3.3	146830	34.0	560
17/05/76	2000	5.6	1328	-	-	2.4	130920	-	527
18/05/76	1120	4.5	1059	26.0	108	2.4	131380	34.5	565
25/05/76	960	4.5	1032	17.5	60	2.8	131380	5.4	530
01/06/76	800	4.6	1060	7.5	48	3.1	128650	27.0	573
02/06/76	750	3.7	-	-	-	2.9	132290	-	538
08/06/76	1120	4.2	1406	35.0	122	3.5	119560	69.5	414
15/06/76	1520	4.5	1258	23.0	104	2.1	131380	44.0	557
22/06/76	1000	4.0	1026	26.0	100	2.6	136830	19.0	516
29/06/76	1280	4.0	1116	15.5	74	2.4	131380	37.5	547
06/07/76	540	3.8	957	15.0	70	3.0	138200	27.5	560
13/07/76	500	4.0	1421	10.0	64	5.3	145020	48.0	557
20/07/76	660	4.5	977	8.5	46	1.7	149560	25.5	638
27/07/76	600	9.0	914	21.0	38	0.7	120920	-	253

TABLE A 1.5

BC TIMBER LTD. EFFLUENT DATA 1974 - 1979 (CONTINUED)

DATE	COLOUR	pH	T.S. mg/L	S.S. kg/ADT	V.S.S. mg/L	D.O. mg/L	FLOW m^3/day	BOD_5 kg/ADT	PROD. Tonnes/day
29/07/76	1500	5.3	1204	-	-	0	129560	-	617
03/08/76	960	4.0	1010	8.0	38	3.5	122290	27.0	598
10/08/76	960	4.0	1034	33.5	44	3.6	132290	39.0	433
17/08/76	1060	3.8	1206	13.0	6	1.1	130470	40.0	576
24/08/76	1000	6.1	1136	35.0	84	1.1	138650	57.5	428
30/08/76	600	2.6	F	-	-	2.6	-	-	558
01/09/76	940	3.8	931	22.0	88	0.6	147290	37.0	592
14/09/76	1120	6.0	1575	23.5	74	4.3	129560	34.0	597
21/09/76	1600	5.7	1636	67.5	144	0	-	36.0	615
22/09/76	1000	6.1	1684	-	-	0	-	-	544
28/09/76	1000	4.8	1046	18.5	54	6.2	-	47.5	452
06/10/76	1000	-	804	59.0	64	0	-	84.0	234
12/10/76	680	-	566	55.0	54	5.2	-	21.0	129
19/10/76	1260	-	1135	16.0	48	0.4	-	37.5	558
26/10/76	1900	-	1220	10.5	48	3.5	-	41.5	551
28/10/76	2000	11.0	1566	-	-	2.9	-	-	429
02/11/76	760	-	927	28.0	82	1.5	-	41.5	459
16/11/76	760	-	1108	11.0	-	3.0	119560	38.5	461
22/11/76	1000	6.4	1208	-	-	2.2	107740	-	416
23/11/76	1920	6.6	1487	20.5	94	2.2	-	40.5	617
30/11/76	1300	3.4	1050	7.0	26	3.5	111830	31.0	520
07/12/76	1160	6.0	1071	20.5	90	-	119100	38.5	469
14/12/76	1280	6.0	1322	20.0	40	-	116830	31.5	617
21/12/76	800	6.1	1492	-	-	-	111830	-	556
22/12/76	1300	6.8	1616	17.5	62	-	110470	35.0	576
04/01/77	1120	8.0	1179	24.5	68	-	122290	55.5	403
12/01/77	1300	-	1255	24.5	74	-	111830	25.5	589
18/01/77	1300	7.2	1158	18.0	66	-	119560	35.0	453
24/01/77	1000	5.3	1048	-	-	-	113190	-	502
25/01/77	1240	-	1246	4.5	36	-	113650	30.5	596

TABLE A 1.5

BC TIMBER LTD. EFFLUENT DATA 1974 - 1979 (CONTINUED)

DATE	COLOUR	pH	T.S. mg/L	S.S. kg/ADT	V.S.S. mg/L	FLOW m^3/day	BOD_5 kg/ADT	PROD. Tonnes/day
01/02/77	860	4.8	1093	14.0	62	102740	29.0	563
08/02/77	1460	4.0	1260	17.5	59	110470	34.0	508
15/02/77	2200	6.0	1413	5.5	62	108190	42.5	521
22/02/77	1860	5.8	1480	14.5	70	112740	55.0	514
28/02/77	-	3.8	2126	-	-	106380	-	357
01/03/77	1860	5.0	1460	14.5	96	110470	54.0	540
08/03/77	960	4.0	1240	36.0	160	110920	56.0	374
15/03/77	1100	4.5	1171	83.5	132	109100	62.0	437
21/03/77	--	2.9	-	-	-	108650	-	537
22/03/77	1500	3.9	1240	12.0	84	110010	36.0	553
29/03/77	1100	4.0	1437	16.0	116	110920	42.0	590
06/04/77	1200	6.0	1124	26.0	120	107280	33.5	607
19/04/77	440	6.0	730	18.5	67	95465	45.0	253
26/04/77	600	10.3	1446	59.0	128	113190	57.0	241
04/05/77	1300	7.2	1118	54.5	144	132740	26.0	586
10/05/77	1160	3.8	1101	4.0	36	119560	36.0	561
18/05/77	1000	5.0	1282	8.0	56	122290	38.5	609
24/05/77	1060	3.8	1064	16.0	92	117740	33.0	537
30/05/77	-	5.1	1300	-	-	115010	-	600
31/05/77	1420	5.5	1206	13.5	86	115470	35.5	509
07/06/77	860	-	1027	8.5	42	115010	39.5	430
14/06/77	1360	4.0	1207	9.5	72	122740	36.5	609
21/06/77	1040	6.4	1006	16.0	88	125920	31.0	529
28/06/77	1140	6.4	1191	21.0	92	123200	27.0	598
05/07/77	1000	7.0	1630	45.0	154	134110	35.5	541
12/07/77	960	5.4	1052	17.5	86	148650	-	643
19/07/77	1000	4.8	934	11.5	56	139110	34.0	566
26/07/77	1200	5.4	1136	17.0	9	141380	44.5	628
09/08/77	1000	-	1662	127.5	174	125470	63.0	392
16/08/77	560	3.7	766	13.5	58	146380	30.0	576

TABLE A 1.5

BC TIMBER LTD. EFFLUENT DATA 1974 - 1979 (CONTINUED)

DATE	COLOUR	pH	T.S. mg/L	S.S. kg/ADT	V.S.S. mg/L	FLOW m^3/day	BOD_5 kg/ADT	PROD. Tonnes/day
23/08/77	1200	3.7	976	21.0	45	138200	34.0	578
31/08/77	560	-	899	13.5	54	129560	32.5	543
12/09/77	-	4.2	-	-	-	122740	-	527
13/09/77	660	7.8	1211	55.5	120	120920	61.0	308
20/09/77	640	3.4	900	11.5	44	130920	28.5	553
27/09/77	640	3.6	893	2.0	20	108190	23.0	566
05/10/77	760	3.0	1018	14.5	52	126380	33.0	577
11/10/77	1440	6.1	302	14.5	52	131380	68.0	447
01/11/77	1520	7.0	1519	101.0	130	123200	121.5	251
09/11/77	1080	5.0	1114	25.5	98	125010	40.5	522
15/11/77	960	3.2	1078	9.0	42	127740	33.0	615
22/11/77	680	4.0	1092	11.0	56	119560	24.5	547
29/11/77	1240	5.0	1270	15.0	48	121830	44.0	517
06/12/77	900	3.8	1190	3.5	12	112740	40.0	442
13/12/77	900	6.9	1176	53.0	81	116380	50.5	358
22/12/77	1100	4.8	1217	11.0	52	112740	38.0	477
04/01/78	3600	-	1960	222.0	220	124100	186.0	196
10/01/78	1060	4.0	1164	7.5	38	11830	30.5	589
17/01/78	840	4.0	1169	11.0	69	107740	28.0	551
24/01/78	900	4.0	1017	4.5	46	107740	33.0	546
25/01/78	-	3.7	-	-	-	110470	-	510
31/01/78	1400	4.5	1377	17.5	68	120010	44.5	539
07/02/78	900	6.8	1005	21.0	60	116830	56.5	359
14/02/78	1000	3.8	1021	9.0	52	122740	33.0	539
21/02/78	1000	5.2	1510	79.0	-	-	36.0	479
01/03/78	1000	6.0	1100	16.5	48	-	28.5	570
07/03/78	1900	6.8	1312	55.0	134	123200	64.5	402
14/03/78	1040	5.0	1125	13.5	66	125470	37.0	541
22/03/78	1040	4.2	1141	10.5	40	121380	38.5	555
04/04/78	2400	5.2	688	64.5	160	129110	49.0	527

TABLE A 1.5

BC TIMBER LTD. EFFLUENT DATA 1974 - 1979 (CONTINUED)

DATE	COLOUR	pH	T.S. mg/L	S.S. kg/ADT	V.S.S. mg/L	FLOW m^3/day	BOD_5 kg/ADT	PROD. Tonnes/day
11/04/78	1040	3.5	1191	5.0	40	-	26.0	563
18/04/78	900	4.0	1256	10.0	60	-	41.0	586
19/04/78	-	2.7	-	6.0	-	-	-	583
25/04/78	520	5.3	796	9.0	60	113190	44.0	334
02/05/78	950	4.8	1128	19.5	74	-	36.5	582
09/05/78	1200	5.3	1082	-	88	120010	30.0	529
17/05/78	1300	5.0	1047	13.5	106	-	28.5	567
22/05/78	-	6.4	-	9.0	-	109100	-	559
23/05/78	860	3.8	927	17.0	81	-	32.0	520
30/05/78	1600	3.3	1222	12.5	86	-	22.5	588
08/06/78	800	2.9	1090	11.3	48	-	37.2	528
14/06/78	951	5.1	1082	8.4	40	129560	44.0	567
20/06/78	1600	3.4	951	7.4	46	-	31.6	553
27/06/78	1200	5.9	1140	45.9	62	-	38.2	449
04/07/78	1100	5.8	864	34.0	62	-	33.0	352
11/07/78	2000	4.8	1356	15.0	-	-	50.0	546
12/07/78	-	7.6	1690	-	-	-	-	561
18/07/78	1040	3.0	1290	13.0	32	-	35.0	547
25/07/78	1200	4.8	897	4.5	28	-	25.5	584
02/08/78	1700	5.5	1220	4.5	48	-	29.0	638
08/08/78	2000	6.1	1551	25.5	62	-	37.5	589
17/08/78	-	10.6	2322	136.5	122	-	-	198
22/08/78	1700	6.4	1408	42.0	122	-	64.0	350
30/08/78	1200	4.2	1125	18.5	52	-	32.0	519
12/09/78	800	4.1	767	10.5	38	-	26.0	471
19/09/78	1200	-	899	3.5	16	-	25.0	577
26/09/78	-	10.4	688	30.5	-	116380	-	261
27/09/78	2000	7.9	1731	4.0	16	119100	58.5	532
03/10/78	1600	3.9	1319	10.5	42	131380	46.0	595
10/10/78	1320	4.1	1192	4.0	-	128650	39.5	584

TABLE A 1.5

BC TIMBER LTD. EFFLUENT DATA 1974 - 1979 (CONTINUED)

DATE	COLOUR	pH	T.S. mg/L	S.S. kg/ADT	V.S.S. mg/L	FLOW m^3/day	BOD_5 kg/ADT	PROD. Tonnes/day
17/20/78	1680	6.5	1729	84.5	188	104560	31.5	582
24/10/78	1200	5.5	846	18.5	52	120470	37.0	421
06/11/78	-	10.4	1364	-	-	103650	-	253
07/11/78	1600	6.6	1188	33.5	117	122840	38.0	484
14/11/78	2000	5.6	1249	12.0	44	114100	33.5	565
21/11/78	800	3.3	932	9.5	32	127740	30.0	549
22/11/78	-	6.8	808	15.5	-	120920	-	516
28/11/78	1480	5.8	1325	10.5	36	119560	48.0	576
05/12/78	1200	3.7	1475	14.0	60	120010	31.5	561
12/12/78	1280	5.2	1155	30.5	112	118650	36.0	529
21/12/78	1280	5.4	1825	117.5	262	115920	33.0	603
28/12/78	960	-	1783	-	380	113650	-	689
10/01/79	960	7.9	1391	-	226	119100	47.0	434
16/01/79	800	8.2	1100	82.0	158	118650	70.5	236
23/01/79	1240	5.8	1345	40.0	110	125470	39.5	537
06/02/79	1200	3.4	1345	31.5	104	112740	34.5	518
13/02/79	1500	4.8	1292	25.5	56	126830	45.0	518
20/02/79	1400	6.9	1714	55.5	140	114100	49.5	563
27/02/79	1200	5.0	1183	11.5	72	114100	31.5	540
06/03/79	2000	6.8	1096	31.0	120	120470	44.0	488
13/03/79	1800	6.9	1705	67.5	250	118190	41.5	558
20/03/79	-	5.3	1388	-	-	116830	-	553
21/03/79	1840	4.9	1438	14.5	72	115010	43.0	537
28/03/79	1600	6.7	1651	24.5	80	124560	52.0	588
03/04/79	980	4.1	1314	23.0	60	116830	41.5	582
11/04/79	2100	6.8	1747	11.8	60	129110	72.0	560
25/04/79	1600	10.6	888	70.8	120	110470	74.0	189
01/05/79	1600	3.8	1111	11.5	78	115920	35.0	530
08/05/79	800	6.1	1125	19.0	4	131830	44.0	530
15/05/79	480	6.6	1182	34.5	112	124100	55.0	466

TABLE A 1.5

BC TIMBER LTD. EFFLUENT DATA 1974 - 1979 (CONTINUED)

DATE	COLOUR	pH	T.S. mg/L	S.S. kg/ADT	V.S.S. mg/L	FLOW m^3/day	BOD_5 kg/ADT	PROD. Tonnes/day
22/05/79	1180	6.8	1156	14.0	64	127290	47.0	541
29/05/79	900	7.3	1343	19.5	54	125920	51.0	545
05/06/79	820	6.5	1079	4.0	32	131380	57.5	580
13/06/79	1200	6.0	1015	13.5	68	129110	38.5	512
19/06/79	1000	7.1	1402	16.0	40	135010	62.0	482
27/06/79	960	6.7	942	17.5	46	126380	31.5	551
04/07/79	1000	6.1	1341	23.5	44	133650	-	524
10/07/79	1100	7.4	329	19.0	64	137740	43.5	521
17/07/79	1300	7.3	1382	37.5	90	151380	50.5	569
24/07/79	800	5.2	1420	123.5	192	129110	89.0	349
31/07/79	800	5.9	1154	9.5	40	128200	36.5	528
07/08/79	800	5.4	1006	25.0	46	118190	39.5	449
14/08/79	-	2.5	1392	14.5	78	120010	27.5	595
22/08/79	-	4.0	1034	18.0	0.7	100920	41.5	342
19/11/79	-	5.7	1132	15.5	-	141830	43.0	585

TABLE A 1.6

BC TIMBER LTD. EFFLUENT DATA (GRAB SAMPLES)

1974 - 1979 (STATION PE - 1272)

Date	pH	S.S. mg/L	Cond. us/cm	Temp. °C	Color T.A.C.	ALK. mg/L	TOC mg/L	TKN mg/L	Ortho P. mg/L	Tot. Phos. mg/L	SO_4 mg/L	Tan. Lig. mg/L	Fec. Col. MPN	Tot. Col. MPN
16/1/74	-	303	1890	26.5	4540	-	-	-	-	-	-	305	200	22000
19/2	6.0	184	1280	25.5	1860	-	-	-	-	-	-	78	-	-
23/1/75	-	190	1950	25	1325	-	266	2	1.41	1.55	-	10	<200	<200
10/3	6.8	-	1500	24	-	-	257	2	0.575	0.848	-	120	-	14000
29/5	6.3	-	1375	23	-	38	315	2	0.62	1.01	70.7	150	-	-
25/6	7.9	-	1090	13.5	-	30.6	195	2	0.7	0.96	70.8	150	-	-
9/7	7.0	-	3500	32	-	-	500	3	0.45	1.12	123	150	-	-
27/11	2.8	95	1500	23.5	-	<0.5	230	1	0.555	0.647	72.3	90	-	-
28/1/76	7.3	-	1400	28	-	-	226	2	0.705	1.2	87	100	-	13000
25/2	5.8	225	1800	27.5	-	90.8	275	2	1.3	1.86	228	144	-	-
31/3	5.0	391	1750	26	-	-	345	2	1.3	1.75	147	150	-	4100
17/5	5.6	133	1650	28.5	-	128	260	2	0.68	0.849	104	140	-	110000
2/6	3.7	96	1050	26.5	-	-	192	2	0.525	0.596	110	85	<2000	2000
29/7	5.3	85	1590	33	-	11.9	137	1.76	0.79	0.905	98	120	<200	<200
30/8	2.6	81	2080	36	-	<0.5	183	2	0.58	0.652	64.2	85	<200	<200
22/9	6.1	427	1850	32	-	-	225	2	0.597	1.24	-	85	<200	4600
28/10	11.0	121	1750	31	-	387	435	2	-	0.27	98.8	260	<200	<200
22/11	6.4	80	1750	28	-	98.5	206	2	0.58	0.714	67.6	70	<200	1300
21/12	6.1	257	1650	26.5	-	-	173	2	0.988	1.51	114	50	-	-
24/1/77	5.3	69	1550	27	-	21.7	150	3	0.537	0.676	77.3	110	50	2400
28/2	3.8	225	1850	31	2280	129	621	6	0.7	1.1	167	220	<200	<200
21/3	2.9	174	1810	15	1460	<0.5	316	3	0.81	0.9	128	140	-	-
30/5	5.1	171	1380	-	1439	20.1	273	-	0.7	0.885	106	140	-	-
12/9	4.2	67	1360	25	1037	<0.5	185	-	0.656	0.76	96.4	100	<2000	<2000
15/10	-	56	1410	20	1325	<0.5	270	2	0.73	0.905	109	120	-	-
15/12	-	40	1500	17	1420	49.7	216	-	0.603	0.7	152	110	-	-
25/1/78	3.7	90	1400	16	1400	<0.5	325	-	0.728	0.799	-	180	-	-
14/2	3.8	53	1290	15	1010	<0.5	220	2	0.735	0.828	79.3	140	-	-
14/3	5.0	96	1150	14	930	64.6	155	-	0.457	0.616	86.3	0.7	-	-
19/4	2.7	79	2000	17	1450	<0.5	330	-	0.82	0.828	228	110	-	-
22/5	6.4	57	1920	16	2000	<0.5	270	-	0.725	0.803	140	95	-	-
14/6/78	5.1	79	1240	18	1250	34	250	-	0.648	0.76	52.7	100	<2000	540000
28/6	-	137	1220	-	-	-	-	-	-	-	-	-	-	-
12/7	7.6	71	1730	-	2400	183	415	-	-	0.795	-	210	-	-
27/7	-	54	540	-	-	-	-	-	-	-	-	-	-	-
17/8	10.6	940	1690	21	1580	-	96	-	-	1.3	145	150	-	-
31/8	-	47	1550	-	-	-	-	-	-	-	-	-	-	-
19/9	-	38	1970	-	-	-	-	-	-	-	-	-	-	-
26/9	10.4	104	682	20.5	640	152	120	-	0.14	0.24	72.3	60	-	-
12/10	-	31	1150	-	-	-	-	-	-	-	-	-	-	-
25/10	-	67	930	-	1070	37.3	162	-	0.645	0.783	52.9	70	-	-
6/11	10.4	-	1440	-	-	-	-	-	-	-	-	-	-	-
22/11	6.8	50	1020	-	1200	54	135	-	0.336	0.856	41.2	55	-	-
5/12	3.7	47	1050	-	-	-	-	-	-	-	-	-	-	-
20/3/79	5.3	67	1610	-	1460	13.8	259	-	0.79	1.06	166	120	-	-
19/11	5.7	44	1210	-	1400	-	225	-	0.67	0.745	100	130	-	-

TABLE A 1.7
SELKIRK EFFLUENT DATA
1973 - 1980 (STATION PE - 141)

Date	Color T.A.C.	pH	T.S. mg/L	T.D.S. mg/L	S.S. mg/L	Cond. us/cm	Temp. °C	D.O. mg/L	TURB. J.T.U.	FLOW m^3/D	TOC mg/L	BOD_5 mg/L	NH_3 mg/L	NO_2 NO_3 mg/L	TKN mg/L	Tot. N. mg/L	Ortho P. mg/L	Tot. Phos. mg/L	Fec. Col. MPN	Tot. Col. MPN
17/1/73	-	7.3	-	-	45	-	10	4	-	-	30	20	-	-	-	-	-	-	-	-
16/5	-	7.5	-	-	9.4	-	15.2	2	-	-	11	<10	-	-	-	-	-	-	-	-
17/7	-	7.4	-	-	85	-	-	-	-	-	30	<10	-	-	-	-	-	-	-	-
4/4/74	-	7.3	236	-	37	380	11	5.2	-	-	25	27	-	-	-	-	-	-	-	-
26/11	-	7.4	234	-	44	400	12.5	3.5	20	-	-	29	-	-	-	-	-	-	-	-
4/3/75	40	7.4	240	-	-	320	7	10.3	24	-	34	33	-	0.48	17	17.48	2.46	4.87	280000	920000
29/5	10	7.4	196	-	-	200	11	2.8	-	-	22	16	1.02	4.01	5	-	1.12	1.78	<2000	-
26/8	-	6.8	142	-	7	191	-	-	-	-	-	<10	-	-	-	-	-	-	-	-
3/9	-	7.2	174	-	7	275	-	-	-	-	-	<10	-	-	-	-	-	-	-	-
24/9	-	7.1	274	-	73	399	-	-	-	-	-	58	-	-	-	-	-	-	13300	240000
11/12	-	7.4	300	-	103	265	12.8	2	-	-	-	67	-	-	-	-	-	-	-	-
9/2/76	-	-	-	-	30	-	-	-	-	292.81	-	52.4	-	-	-	-	-	-	-	-
17/5	-	6.5	208	-	58	170	12	7.8	-	119.03	-	51	-	-	-	-	-	-	<2000	-
15/6	20	6.9	228	-	47	255	13.5	8.5	-	126.81	34	36	-	0.49	21	21.49	5.8	7.25	800	-
22/6	-	-	-	-	30	-	-	-	-	110.93	-	54	-	-	-	-	-	-	-	-
19/8	15	6.8	-	-	-	145	15	7.2	-	90.474	-	22	-	0.32	6	0.70	6.32	1.35	<200	1700
30/9	-	7.4	216	-	35	275	17	3	-	115.73	-	42	-	-	-	-	-	-	54000	642000
7/10	-	-	-	-	122	-	-	-	-	209.09	-	49.6	-	-	-	-	-	-	-	-
24/11	-	7.3	252	-	65	282	14	2.4	-	158.26	-	25	-	-	-	-	-	-	20	330
13/12	-	-	-	-	30	-	-	-	-	195.33	-	28.4	-	-	-	-	-	-	35000	-
28/2/77	-	7.3	274	-	56	412	10	5	-	-	-	77	-	-	-	-	-	-	240000	240000
26/3	-	-	-	-	46	-	-	-	-	-	-	32.8	-	-	-	-	-	-	-	-
25/4	-	-	-	-	44	-	-	-	-	-	-	31.7	-	-	-	-	-	-	-	-
29/8	-	7.5	130	-	30	176	17	7.6	-	-	-	<10	-	-	-	-	-	-	790	24000
13/9	-	-	-	-	52	-	-	-	-	-	-	33.4	-	-	-	-	-	-	-	-
29/11	-	7.5	296	-	72	460	-	-	-	-	-	77	-	-	-	-	-	-	49000	350000
8/12	-	7.6	438	-	59	819	-	-	-	-	-	60	52.8	2.48	62	-	-	-	-	-
20/12	-	-	-	-	100	-	-	-	-	-	-	65	-	-	-	-	-	-	-	-
7/1/78	-	-	-	-	82	-	-	-	-	-	-	58	-	-	-	-	-	-	-	-
24/1	-	7.3	280	-	58	430	-	4.6	-	167.28	-	61	14.3	-	-	-	-	-	130000	350000
14/3	20	7.3	234	-	44	349	10	-	-	102.25	-	94	13	-	-	-	3.42	5.3	-	-
18/4	-	6.7	206	-	28	342	12	-	-	70.18	-	15	11.5	-	-	-	4.4	5.22	<20	-
19/5	-	-	-	-	72	-	-	-	-	65.448	-	65	-	-	-	-	-	-	-	-
25/7	-	-	-	-	61	-	-	-	-	52.833	-	44	-	-	-	-	-	-	-	-
26/9	15	6.9	210	-	58	261	16	-	-	92.524	-	39	7.1	-	-	-	2.39	2.78	24000	-
17/1/79	-	-	-	-	36	-	-	-	-	-	-	30	-	-	-	-	-	-	-	-
9/4	-	7.1	214	-	55	-	-	-	-	89.105	-	72	5.3	-	-	-	1.98	3.86	-	-
29/6	-	-	-	-	32	-	-	-	-	43.505	-	28	-	-	-	-	-	-	-	-
17/9	-	-	-	-	34	-	-	-	-	88.319	-	32	-	-	-	-	-	-	-	-
14/11	-	7.1	-	-	29	305	-	-	-	71.635	-	42	8.05	0.34	-	-	2.74	4.18	3500	-
17/12	-	-	-	-	40	-	-	-	-	70.367	-	38	-	-	-	-	-	-	-	-
19/2/80	-	7.6	-	-	31	392	-	-	-	-	-	35	-	-	-	-	-	-	24000	-

TABLE A 1.8
CASTLEGAR TREATED EFFLUENT DISCHARGE
1973 - 1979 (STATIO PE - 4006)

Date	Color T.A.C.	pH	T.S. mg/L	T.D.S. mg/L	S.S. mg/L	Cond. us/cm	Temp. °C	D.O. mg/L	TURB. J.T.U.	FLOW m^3/D	TOC mg/L	BOD_5 mg/L	NH_3 mg/L	NO_2 NO_3 mg/L	TKN mg/L	Tot. P. mg/L	Ortho P. mg/L	Tot. Phos. mg/L	Fec. Col. MPN	Tot. Col. MPN
17/11/73	-	7.5	-	-	33	-	3	0.2	-	-	45	32	-	-	-	-	-	-	240000	-
16/5	-	8.9	-	-	9.2	-	19.5	7.8	-	-	58	34	-	-	-	-	-	-	79000	-
13/7	-	-	-	-	79	-	-	-	-	-	-	75.5	-	-	-	-	-	-	-	-
11/7	-	9.2	-	-	52	-	19	-	-	-	68	25	-	-	-	-	-	-	17000	-
9/4/74	-	8.3	535	-	53	-	9	8.5	-	-	-	57	-	-	-	-	-	-	20000	22000
30/7	-	-	-	-	14	-	-	-	-	-	-	17	-	-	-	-	-	-	-	-
16/10	-	-	-	-	53	-	-	-	-	-	-	55	-	-	-	-	-	-	-	-
25/11	-	8	544	-	54	900	5	2.5	20	-	41	41	-	-	-	-	-	-	220000	920000
21/1/75	-	-	-	-	70	-	-	-	-	-	-	70	-	-	-	-	-	-	-	-
15/4	-	-	-	-	92	-	-	-	-	-	-	84	-	-	-	-	-	-	1100000	-
27/1/76	-	-	-	-	18	-	-	-	-	-	-	27	-	-	-	-	-	-	8000	-
29/1	-	7.9	528	-	9	940	1.0	9.9	-	-	-	14	-	-	-	-	-	-	49000	-
27/5	40	7.9	574	-	40	800	17	-	-	-	42	29	19.3	1.85	23	-	4.8	5.47	<2000	-
15/6	40	9.2	522	-	37	530	17.5	9.8	-	-	41	48	7.7	0.96	15	-	1.28	3.15	<200	-
19/8	60	8	542	-	18	700	17	5.4	-	-	36	18	6.2	1.19	11	-	3.75	4.27	-	<2000
19/10	-	-	-	-	6	-	-	-	-	-	-	12	-	-	-	-	-	-	-	-
24/11	40	8.4	542	-	5	530	3.1	9.6	8.6	-	22	11	15.8	0.96	19	-	4.87	5.22	800	1700
7/2/77	-	7.6	562	-	7	1000	1.0	8.5	-	590.51	-	14	-	-	-	-	-	-	3300	3300
8/2	-	-	-	-	32	-	-	-	-	670	-	12	-	-	-	-	-	-	-	-
17/5	-	-	-	-	144	-	-	-	-	514.8	-	45.6	-	-	-	-	-	-	-	-
26/5	-	9.9	584	-	100	720	14	9	-	757.06	-	52	-	-	-	-	-	-	-	-
29/8	-	8.2	590	-	39	860	17	4.2	-	670	-	13	-	-	-	-	-	-	<200	1300
9/12	-	7.2	572	-	33	891	-	-	-	851.69	-	19	-	-	-	-	-	-	<20000	<20000
13/2	-	-	-	-	11	-	-	-	-	1287	-	15	-	-	-	-	-	-	-	-
14/3/78	-	-	-	-	23	-	-	-	-	851.69	-	20	-	-	-	-	-	-	-	-
18/4	-	8.9	550	-	59	790	11	-	-	881.98	-	44	14.7	-	-	-	1.99	4	<2000	-
13/6	-	-	-	-	14	-	-	-	-	757.06	-	28	-	-	-	-	-	-	-	-
12/7	-	7.9	574	-	8	935	-	-	-	-	-	14	19.9	-	-	-	5.12	5.48	-	-
12/9	-	-	-	-	10	-	-	-	-	382.32	-	14	-	-	-	-	-	-	-	-
26/9	-	8.5	564	-	11	813	15	-	-	-	-	19	4.42	-	-	-	2.95	3.22	20	-
21/11	-	8.8	598	-	53	818	-	-	-	-	-	18	4.58	-	-	-	1.98	2.98	5400	-
12/12	-	-	-	-	92	-	-	-	-	1052.3	-	18.9	-	-	-	-	-	-	-	-
13/3/79	-	-	-	-	14	-	-	-	-	-	-	11	-	-	-	-	-	-	-	-
20/3	-	8.2	412	-	15	704	-	-	-	981.15	-	14	14.5	-	-	-	2.8	3.32	-	-
12/6	-	-	-	-	48	-	-	-	-	-	-	15.9	-	-	-	-	-	-	-	-
28/6	-	8.6	-	-	26	763	-	-	-	-	-	45	-	-	-	-	-	-	17	-
14/11	-	8.5	-	-	35	800	-	-	-	-	-	12	-	-	-	-	-	-	940	-
17/1/73	-	8	-	-	236	-	9	6	-	-	100	140	-	-	-	-	-	-	-	-
16/5	-	8.4	-	-	225	-	15.7	2.9	-	-	107	139	-	-	-	-	-	-	-	-
25/11/74	-	-	870	-	200	1160	-	-	-	-	130	166	-	-	-	-	-	-	-	-

APPENDIX 2

A2.1 Analysis of Arrow Lakes Reservoir to Determine Solar Heat Flux Contribution

A2.2 Potential Oxygen Sag

A2.3 Field Notes - BC Timber Ltd. Plume Study

A2.4 Field Notes - Arrow Lakes Reservoir Study

APPENDIX A 2.1

ANALYSIS OF ARROW LAKES RESERVOIR TO DETERMINE SOLAR HEAT FLUX CONTRIBUTION

A2.1: Analysis of Arrow Lakes Reservoir to Determine Solar Heat Flux Contribution

Heat Content of Reservoir At anytime t

$$= \sum_{i=0}^{i=32} Vi\ Cp_v\ (Ti - Tref)\ A_s$$

where

- V_i = volume of unit area X depth (usu. 2 m)
- Cp_v = heat capacity (1 000 kcal/m^3 - ^oC)
- T_i = avg. temperature of depth increment (^oC)
- A_s = total surface area of reservoir (2 000 m x 170 000 m)

Advective Heat Flux in = $Qin\ Cp_v\ (Tin - Tref)\ t$

where

- Qin = volumetric flow rate into reservoir (m^3/sec)
- Cp_v = heat capacity (1 000 kcal/m^3 - ^oC)
- Tin = avg. temperature of flow during period
- Tref = reference temperature (0^oC)
- t = time period

Advective Heat Flux Out = $Qout\ Cp_v\ (Tout - Tref)\ t$

where

- Qout = volumetric flow rate from reservoir (m^3/sec)
- Tout = avg. temperature of flow during period

all others as previously defined

Solar heat flux calculated by

Heat flux solar = Heat Content, time t - Heat Content, time t initial - Advective Heat flux in + Advective Heat Flux out

$$\text{Unit solar heat flux} = \frac{\text{Heat flux, solar}}{\text{Total Surface Area X } t}$$

TABLE A 2.1

TEMPERATURE DEPTH DATA

LOWER ARROW LAKE OPPOSITE SYRINGA

Depth (m)	Temperature (°C) at Month and Year				
	06 - 76	06 - 77	08 - 77	05 - 78	08 - 78
0	13.25	-	19.7	-	-
1	13.25	16.6	19.7	7	22
5	13	16.4	19.4	6.7	21
10	13	14.4	19	7	15
15	12	11.2	17.2	7	12.5
20	12	9.4	13.8	-	12
21	12	-	-	-	-
25	-	9.2	11	6.5	10
28	-	6.9	-	-	-
30	-	-	8	6	9.5
35	-	-	7.5	-	8

APPENDIX A 2.2

POTENTIAL OXYGEN SAG

TABLE A 2.2

TEMPERATURE DEPTH DATA

UPPER ARROW LAKE OPPOSITE GALENA

Depth (m)	Temperature (°C) at Month and Year						
	05-75	08-75	04-77	09-77	04-78	06-78	08-78
0	10	20	8	14	5	12	17
2	9.5	16	7	12.5	5	12	16.5
4	7.5	13.5	7	11	5	12	16
6	7	12	6.5	11	5	12	15.5
8	6.5	11	6	10.5	5	12	14.5
10	6	11	6	10.5	5	11.5	13.5
12	5.5	10.5	5.5	10	5	11	11.5
14	5	10	5	10	5	10.5	11
16	5	10	5	10	5	10	11
20	4	9.5	5	9	5	8.5	10
24	4	8.5	4.5	8	5	7.5	9.5
28	4	7.5	4.5	6.5	5	6	9
32	4	6.5	4.5	6	5	5	8
36	4	5.5	4.5	5	5	5	7.5
40	4	5	4.5	5	5	4.5	7
44	4	4.5	4.5	4.5	5	4.5	7

A2.2: Potential Oxygen Sag

The Streeter-Phelps equation yields an oxygen demand due to organic matter decomposition introduced into the stream. The deficit (D) is given by:

$$D = \frac{k_d \, Lo \, (e^{-k_d \frac{x}{u}} - e^{-k_2 \frac{x}{u}})}{k_2 - k_r}$$

Where:
- Lo = ultimate BOD of waste and river
- k_d = k_r = reaction rate for deoxygenation in the river
- k_2 = reaeration coefficient
- x = distance downstream from discharge
- u = stream velocity

The following conditions were used in the treatment of the physical system:

	Low Flow		Low Elevation	
	Regime 1	Regime 2	Regime 1	Regime 2
Elevation (m)	424	424	420.5	419.8
Flow (m^3/sec) Keenleyside Dam	142	142	153	520
confluence to MC Dam	445	425	457	1332
Area (m^2)				
Keenleyside Dam to confluence	3800	3800	2660	2450
confluence to MC Dam	4700	4700	3390	2950
Velocity (m/sec)				
HK Dam to confluence	0.037	0.037	0.058	0.212
confluence to MC Dam	0.095	0.090	0.135	0.452
Depth of Flow (m)				
HK Dam to confluence	11.0	11.0	8.8	8.4
confluence to MC Dam	12.4	12.4	10.0	9.4
Residence Time (D)				
HK Dam to confluence	3.31	3.31	2.15	0.58
confluence to MC Dam	2.81	2.96	1.97	0.59

Other Conditions Used:

Temperature = 20°C

Ultimate BOD of waste = 460 mg/L

Waste Flow = 1.4 m^3/sec

D_L = diffusively of O_2 in water = 2.09 x 10^{-1} m^2/sec

The enumeration coefficients (k_2) were calculated by

$$k_2 = (D_L\, u)^{0.5}\, H^{-1.5}$$

where: D_L = diffusivity of O_2 in H_2O (m^2/sec)
u = stream velocity (m/sec)
H = reservoir depth (m)

	Low Flow		Low Elevation	
	Regime 1	Regime 2	Regime 1	Regime 2
k_2 (D^{-1}) to confluence	0.021	0.021	0.036	0.075
after confluence	0.029	0.034	0.046	0.092

The reaction rate k_d for the waste was calculated:

ultimate BOD of waste = BOD_u = 460 mg/L
5 day BOD of waste = BOD_5 = 300 mg/L
$BOD_5 = BOD_u\,(1 - e^{k\, d5})$
$300 = 460\,(1 - e^{-k_d 5})$
$K_d = 0.21\ day^{-1}$

The ultimate BOD of the waste and river (Lo) was calculated by material balance assuming no upstream BOD using the equation

$$L_o = \frac{BOD_u \times \text{waste flow}}{\text{waste flow} + \text{river flow}}$$

	Low Flow		Low Elevation	
	Regime 1	Regime 2	Regime 1	Regime 2
L_o (mg/L) to confluence	4.491	4.491	4.171	1.235
after confluence	1.443	1.51	1.405	0.483

Set up a table to perform calculations

Distance Downstream From Discharge (km)	Oxygen Reduction (mg/L) Regime 1 Low Flow	Low Elev.	Regime 2 Low Flow	Low Elev
0.5	0.146	0.087	0.146	0.007
1	0.286	0.171	0.286	0.014
2	0.552	0.334	0.552	0.028
3	0.798	0.490	0.798	0.042
4	1.028	0.637	1.028	0.055
5	1.241	0.777	1.241	0.068
6	1.438	0.911	1.438	0.081
7	1.621	1.037	1.621	0.094
Kootenay River Confluence				
8	0.264	0.186	0.289	0.020
9	0.293	0.207	0.320	0.023
10	0.321	0.228	0.35	0.025
15	0.449	0.324	0.487	0.037
20	0.558	0.409	0.602	0.048
25	0.652	0.485	0.699	0.059
29	0.716	0.539	0.765	0.068
30	0.731	0.552	0.780	0.070
30	0.741	0.561	0.791	0.071

A 2.3

Plume Study

September 19, 1980

Summary of Effluent Dispersion Models

TRANSECT #1

1 Soundings Taken Across From:	2 Distance of Soundings From Diffuser Heads (m)	3 Depth of Sounding (m)	4 Conductivity (umhos/cm)	5 Notes
Piling 1	Upstream 65 m	0	127	Surface
		3.5	124	Bottom
halfway between Piling 1 & 2	Upstream 25 m	0	127	Surface
		5.1	127	Bottom
P 3	Downstream 69 m	0	127	Surface
		5.5	127	Bottom
P 4	Downstream 160 m	0	144	Surface
		1.2	135	
		1.6	130	
		3.6	125	
		4.8	110	
		5.7	110	Bottom
P 4.5	Downstream 205 m	0	145	Surface
		1.6	135	
		4.2	120	
		4.9	104	Bottom
P 5	Downstream 252 m	0	145	Surface
		1.4	132	
		3.0	125	
		3.6	112	
		4.0	110	Bottom
P 5.5	Downstream 297 m	0	144	Surface
		1.3	130	
		3.5	112	
		4.1	110	Bottom
P 6	Downstream 343 m	0	142	Surface
		2.0	130	
		4.2	115	
		4.5	110	Bottom
P 6.5	Downstream 389 m	0	130	Surface
		2.8	125	
		3.3	115	
		4.7	114	Bottom
P 7	Downstream 434 m	0	132	Surface
		2.8	124	
		4.2	117	
		6.4	113	Bottom

TRANSECT #1 (Continued)

1 Soundings Taken Across From:	2 Distance of Soundings From Diffuser Heads (m)	3 Depth of Sounding (m)	4 Conductivity (umhos/cm)	5 Notes
P 7.5	Downstream 480 m	0	128	Surface
		2.4	115	
		5.8	110	
		7.3	110	Bottom
P 8.0	Downstream 526 m	0	130	Surface
		1.1	122	
		2.5	112	
		7.6	110	Bottom
P 9.0	Downstream 617 m	0	118	Surface
		2.1	115	
		3.8	110	
		8.3	109	Bottom
P 10	Downstream 709 m	0	118	Surface
		2.7	110	
		5.7	108	
		8.0	108	Bottom

TRANSECT #2

1 Soundings Taken Across From:	2 Distance of Soundings From Diffuser Heads (m)	3 Depth of Sounding (m)	4 Conductivity (umhos/cm)	5 Notes
Piling 1	Upstream 65 m	0	123	Surface
		1.1	115	
		2.3	110	
		9.6	108	Bottom
P 1.5	Upstream 42 m	0	135	Surface
		0.9	122	
		2.7	115	
		4.2	110	
		7.3	109	Bottom
P 2	Upstream 23 m	0	134	Surface
		1.0	125	
		2.0	115	
		4.2	110	
		9.9	108	Bottom
P 2.5	Downstream 23 m	0	130	Surface
		2.4	115	
		5.0	110	
		10.2	107	Bottom
P 3	Downstream 69 m	0	145	Surface
		0.7	125	
		2.5	115	
		10.1	109	Bottom
P 3.5	Downstream 114 m	0	140	Surface
		1.2	130	
		1.9	120-155	fluctuating
		2.7	118	
		5.0	110	
		8.8	108	Bottom
P 4	Downstream 160 m	0	144	Surface
		2.7	125	
		4.0	120	
		7.3	120	Bottom
P 4.5	Downstream 205 m	0	145	Surface
		1.2	135	
		2.3	120	
		3.8	112	
		10.4	110	Bottom
P 5	Downstream 252 m	0	144	Surface
		1.4	125	
		3.3	115	
		10.6	110	Bottom

TRANSECT #2 (Continued)

1 Soundings Taken Across From:	2 Distance of Soundings From Diffuser Heads (m)	3 Depth of Sounding (m)	4 Conductivity (umhos/cm)	5 Notes
P 5.5	Downstream 297 m	0	135	Surface
		2.6	145	
		4.0	135	
		6.0	135	
		7.5	115	
		9.7	110	Bottom
P 6	Downstream 343 m	0	135	Surface
		1.4	140	
		3.2	130	
		6.5	120	
		8.0	117	
		11.7	110	Bottom
P 6.5	Downstream 389 m	0	140	Surface
		5.0	128	
		6.0	115	
		12.1	110	Bottom
P 7	Downstream 434 m	0	142	Surface
		4.8	130	
		5.5	120	
		7.4	115	
		10.4	110	
		12.5	112	Bottom
P 7.5	Downstream 480 m	0	140	Surface
		5.0	135	
		8.2	125	
		10.0	118	
		11.5	108	Bottom
P 8	Downstream 526 m	0	140	Surface
		5.0	135	
		6.5	120	
		8.5	110	
		13.0	110	Bottom
P 9	Downstream 617 m	0	140	Surface
		4.8	130	
		6.2	120	
		7.7	110	
		12.4	110	Bottom
P 10	Downstream 709 m	0	130	Surface
		3.8	120	
		4.5	115	
		6.7	110	
		12.0	108	Bottom

TRANSECT #3

1 Soundings Taken Across From:	2 Distance of Soundings From Diffuser Heads (m)	3 Depth of Sounding (m)	4 Conductivity (umhos/cm)	5 Notes
Piling 1	Upstream 65 m	0	110	Surface
		13.1	110	Bottom
P 1.5	Upstream 42 m	0	110	Surface
		11.6	110	
P 2	Upstream 23 m	0	110	Surface
		10.4	110	Bottom
P 2.5	Downstream 23 m	0	145	Surface
		2.2	120	
		4.1	110	
		10.5	110	Bottom
P 3.0	Downstream 69 m	0	150	Surface
		2.8	140	
		4.5	135	
		6.6	120	
		7.8	115	
		8.6	110	
		12.2	108	Bottom
P 3.5	Downstream 114 m	0	150	Surface
		1.8	140	
		3.6	120	
		4.3	110	
		14.0	107	Bottom
P 4	Downstream 160 m	0	145	Surface
		2.0	135	
		2.6	115	
		3.2	110	
		14.0	107	Bottom
P 4.5	Downstream 205 m	0	148	Surface
		2.0	120	
		3.5	110	
		14.2	107	Bottom
P 5	Downstream 252 m	0	140	Surface
		1.2	130	
		2.0	120	
		3.2	110	
		14.2	107	Bottom
P 6	Downstream 343 m	0	135	Surface
		2.2	115	
		2.9	109	
		14.0	107	Bottom

TRANSECT #3 (Continued)

1 Soundings Taken Across From:	2 Distance of Soundings From Diffuser Heads (m)	3 Depth of Sounding (m)	4 Conductivity (umhos/cm)	5 Notes
P 7	Downstream 434 m	0	138	Surface
		2.7	130	
		3.9	120	
		5.5	110	
		13.6	107	Bottom
P 8	Downstream 526 m	0	135	Surface
		5.3	130	
		6.1	120	
		11.0	107	
		12.2	107	Bottom
P 9	Downstream 617 m	0	138	Surface
		4.0	125	
		4.4	115	
		7.3	110	
		11.4	107	Bottom
P 10	Downstream 709 m	0	136	Surface
		6.1	120	
		7.7	112	
		10.0	110	
		13.0	108	Bottom

TRANSECT #4

1 Soundings Taken Across From:	2 Distance of Soundings From Diffuser Heads (m)	3 Depth of Sounding (m)	4 Conductivity (umhos/cm)	5 Notes
Piling 1	Upstream 65 m	0	109	Surface
		15.0	107	Bottom
P 2	Upstream 23 m	0	112	Surface
		14.2	107	Bottom
P 2.5	Downstream 23 m	0	110-100+	fluctuating
		2.5	110	
		13.2	107	Bottom
P 3.0	Downstream 69 m	0	140	Surface
		4.0	140	
		7.0	150	
		8.6	118	
		10.0	110	
		14.0	107	Bottom
P 3.5	Downstream 114 m	0	143	Surface
		2.6	130	
		4.0	118	
		4.6	110	
		14.0	107	Bottom
P 4	Downstream 160 m	0	140	Surface
		1.8	135	
		3.3	115	
		4.6	110	
		14.6	107	Bottom
P 4.5	Downstream 205 m	0	138	Surface
		2.0	115	
		4.0	107	
		14.2	107	Bottom
P 5	Downstream 252 m	0	136	Surface
		1.5	125	
		2.6	110	
		14.8	107	Bottom
P 6	Downstream 343 m	0	135	Surface
		3.3	120	
		3.8	110	
		13.0	107	Bottom
P 7	Downstream 434 m	0	138	Surface
		3.2	130	
		5.5	125	
		6.8	110	
		13.7	107	Bottom

TRANSECT #4 (Continued)

1 Soundings Taken Across From:	2 Distance of Soundings From Diffuser Heads (m)	3 Depth of Sounding (m)	4 Conductivity (umhos/cm)	5 Notes
P 8	Downstream 526 m	0	135	Surface
		6.1	125	
		6.9	115	
		8.5	109	
		12.0	107	Bottom
P 9	Downstream 617 m	0	140	Surface
		3.5	130	
		5.2	120	
		7.0	112	
		9.0	107	
		11.9	107	Bottom
P 10	Downstream 709 m	0	135	Surface
		5.0	125	
		6.8	110	
		15.0	107	Bottom
1/2 way between P 10 and Robson Wharf South Side	Downstream 1400 m	0	110	Surface
		9.2	113	
		13.8	110	Bottom
1/2 way between P 10 and Robson Wharf North Side	Downstream 1400 m	0	120	Surface
		3.8	115	
		7.0	111	
		12.6	111	Bottom
1/2 way midstream	Downstream 1400 m	0	120	Surface
		4.0	115	
		6.7	110	
		13.6	107	Bottom
Robson Wharf ?	Downstream 2150 m	0	112	Surface
		14.5	110	Bottom
South Side	Downstream 2150 m	0	112	Surface
		12.4	110	Bottom
North Side	Downstream 2150 m	0	112	Surface
		13.6	111	Bottom
1/4 way between P 10 & Robson Wharf Midstream	Downstream 1050 m	0	132	Surface
		2.1	125	
		6.0	120	
		8.5	115	
		9.6	110	
		12.7	109	Bottom

TRANSECT #5

1 Soundings Taken Across From:	2 Distance of Soundings From Diffuser Heads (m)	3 Depth of Sounding (m)	4 Conductivity (umhos/cm)	5 Notes
Piling 1	Upstream 65 m	0	112	Surface
		14.8	108	Bottom
P 1.5	Upstream 42 m	0	114	Surface
		15.0	110	Bottom
P 2.5	Downstream 23 m	0	112	Surface
		13.2	110	Bottom
P 3.0	Downstream 69 m	0	145	Surface
		2.6	125	
		3.7	115	
		6.8	112	
		14.0	110	Bottom
P 3.5	Downstream 114 m	0	130	Surface
		2.0	120	
		3.1	115	
		7.0	110	
		13.5	109	Bottom
P 4	Downstream 160 m	0	135	Surface
		2.2	120	
		3.0	114	
		14.9	107	Bottom
P 4.5	Downstream 205 m	0	130	Surface
		4.3	120	
		5.6	115	
		10.0	110	
		14.8	109	Bottom
P 5	Downstream 252 m	0	130	Surface
		3.6	120	
		9.6	115	
		8.4	110	
		15.0	109	Bottom
P 6	Downstream 343 m	0	130	Surface
		4.5	120	
		7.0	115	
		11.3	110	
		14.5	109	Bottom
P 7	Downstream 434 m	0	128	Surface
		4.0	120	
		5.0	110	
		12.2	108	Bottom

TRANSECT #5 (Continued)

1 Soundings Taken Across From:	2 Distance of Soundings From Diffuser Heads (m)	3 Depth of Sounding (m)	4 Conductivity (umhos/cm)	5 Notes
P 8	Downstream 526 m	0	132	Surface
		5.0	125	
		6.1	115	
		6.9	110	
		12.2	109	Bottom
P 9	Downstream 617 m	0	135	Surface
		5.3	125	
		5.6	115	
		6.4	110	
		10.9	109	Bottom
P 10	Downstream 709 m	0	135	Surface
		6.0	125	
		7.4	118	
		8.1	110	
		12.4	109	Bottom

SUMMARY OF EFFLUENT DISPERSION MODELS

General:

The dilution of mill effluent into the river is described by modelling the plume through two distinct regimes. These are as follows:

- initial dilution caused as the warm mill effluent rises from the diffuser ports and impinges the river surface to establish a stable surface layer, and

- subsequent dilution of the surface plume gradually as it travels downriver.

Initial Dilution

The following three equations were developed to predict the location and initial dilution of the mill effluent plume centreline as it reaches the surface of the river.

$$H = 0.00197\ K^{-0.234}\ F^{2.584}\ V^{1.569} \qquad \text{Eq. 1}$$

$$S_o = 1.7015\ K^{-1.198}\ H^{1.267} \qquad \text{Eq. 2}$$

$$S_o(\text{min}) = 0.992\ F^{0.359}\ (V/D)^{0.609} \qquad \text{Eq. 3}$$

where:

H = distance downstream of diffuser ports where plume centreline surfaces (m)

K = diffuser jet velocity divided by river velocity (6 ports, each 0.4064 m diam.)
= $vj \Big/ \left(\frac{Pr - Pe}{pr}\ g\ D\right)^{1/2}$

Vj = jet velocity (m/s)

Pr = density of river water

Pe = density of effluent

g = gravitational constantant (9.8 m/s^2)

D = diffuser port diameter (m)

V = vertical depth of diffuser port b (m)

So = initial dilution of effluent in river water at point of impingement at surface

v = velocity of current in river (m/s)

So (min) = initial dilution of plume centreline at river surface from Shirazi & Davis data when river velocity approaches zero.

Equation 1 and Equation 2 were developed by linear regression of the field data collected during the plume modelling studies completed on 19 September 1980. At low river velocities Equation 2 was found to be unreliable. Equation 3 was developed by linear regression of selected "data" points from nomograms published by Shirazi & Davis (EPA - R2-72-05a) for rising plumes in non-stratified receiving waters with no ambient velocity. Predictions from Equation 3 were used whenever the initial dilution predicted by Equation 2 were less than those predicted by Equation 3.

Downriver Dilution

Equation 4 was developed from linear regression of the data from the 19 September 1980 survey to predictj dilution of the surface plume after initial surface impingement as it moves downriver with the current.

$$S = 0.02617\ So \left(\frac{x - H}{v}\right)^{0.234} \qquad \text{Eq. 4}$$

where S = total number of dilutions with river water at plume centreline

x = total distance downriver from diffuser ports (m)

APPENDIX A 2.4

DEPTH, TEMPERATURE, DISSOLVED OXYGEN PROFILES LOWER ARROW LAKE FIELD NOTES SEPTEMBER, 1980

Lake Station #1 - Lower Arrow Lake

Location: Hugh Keenleyside Dam - on floating pier in front of dam face

TEMPERATURE & DISSOLVED OXYGEN PROFILES

Time: 5:30-6:30 PM/September 20, 1980

Depth m	D.O. PPM	Temp. °C			
0	9.2	15.75	Surface	Sat value	% Saturation
1	9.9	15.75		9.975	99
2	"	"			
3	"	"			
4	"	"			
5	"	"			
6	"	"			
7	"	"	-Secchi Depth/	H_2O Sample	(Turbidity - 57
8	"	"			
9	"	"			
10	"	"		9.975	99
11	9.0	"			
12	9.0	"	H_2O Sample/ (Turbidity - .48)	Phyto. & Zooplankton	Tows
13	9.0	14.25			
14	8.8	14.0		10.4	85
15	9.0	13.0		10.6	85
16	9.0	13.0		10.6	
17	8.8	12.0		10.0	81.5
18	9.0	11.75			
19	9.1	12.0		10.8	
20	9.0	11.5		10.95	82
21	9.1	10.75			
22	9.1	11.0		11.1	82
23	8.7	10.5			
24	8.8	10.75			
25	8.8	10.0			
26	8.8	9.25	H_2O Sample	(Turbidity- .42)	
27	9.0	9.25			
28	8.8	9.0			
28.5	8.8	9.0	Bottom/	Phyto & Zooplankton	Tows

Lake Station #2 - Lower Arrow Lake

Location: midlake - 1700 metres from dam face

TEMPERATURE & DISSOLVED OXYGEN PROFILES

Time: 3:45-4:30 PM/September 20, 1980

Depth m	D.O. PPM	Temp. °C			
0	9.6	15.75	Surface	Sat Value	% Saturation
1	9.7	15.75		9.975	97
2	9.7	15.75			
3	9.7	15.75			
4	9.4	15.75			94
5	9.4	15.75			
6	9.4	15.75	Secchi Depth/	H_2O Sample	(Turbidity -.49)
7	9.4	15.75			
8	9.4	15.75			
9	9.4	15.75			
10	9.4	15.75		9.975	94
11	9.4	15.5	H_2O Sample/ (Turbidity - .46)	Phyto. & Zooplankton	Tows
12	9.4	15.0			
13	9.4	14.5			
14	9.4	13.0		10.6	89
15	9.4	12.75			
16	9.4	11.25			
17	9.4	11.0		11.1	85
18	9.4	10.75			
19	9.4	10.5		11.2	84
20	9.4	10.25			
21	9.4	9.75			
22	9.4	9.75			
23	9.4	9.5		11.4	82
24	9.4	9.5			
25	9.4	9.5			81
26	9.4	9.0	H_2O Sample	11.6	- (Turbidity - .35)
27	9.4	9.0			
28	9.4	9.0			
29	9.0	9.0			77.6
30	9.0	9.0	Bottom/	Phyto. & Zooplankton	Tows

Lake Station #3 - Lower Arrow Lake

Location: mid-lake 2900 metres from dam face

TEMPERATURE & DISSOLVED OXYGEN PROFILES

Depth m	D.O. PPM	Temp. °C	Time: 2:30-3:30 PM/September 20, 1980		
0	9.7	15.75	Surface	Sat value	% Saturation
1	9.4	15.5		9.975	91
2	9.4	15.75			
3	9.4	15.75			
4	9.0	15.75			90
5	8.6	15.75			86
6	8.6	15.5	Secchi Depth/	H_2O Sample	(Turbidity - .40)
7	8.9	15.5			
8	8.9	15.5			
9	8.9	15.5			
10	9.0	15.5		10.05	90
11	9.0	15.25			
12	8.9	15.0	H_2C Sample/ (Turbidity - .37)	Phyto. & Zooplankton	Tows
13	8.7	14.0			
14	8.7	13.25			
15	8.7	13.0		10.6	82
16	8.7	12.25			
17	8.9	11.25			
18	9.0	11.0		11.1	81
19	9.0	10.5		11.2	80
20	8.9	10.25			
21	8.7	10.0		11.3	77
22	9.0	10.0			
23	9.0	10.0			
24	9.0	10.0			
25	9.1	9.75			
26	9.1	9.25			
27	9.1	9.25			
28	9.1	9.0	H_2O Sample		(Turbidity - .30)
29	9.1	9.0		11.6	78
30	9.1	9.0			
31	9.1	9.0			
32	9.1	9.0			
33	8.9	9.0			
34	8.9	9.0			

Lake Station #3 (Continued) - Lower Arrow Lake

Location: mid-lake 2900 metres from dam face

TEMPERATURE & DISSOLVED OXYGEN PROFILES

Time: 2:30-3:30 PM/September 20, 1980

Depth m	D.O. PPM	Temp. °C	Sat Value	% Saturation
35	8.7	9.0		
36	8.7	9.0		
37	8.7	8.75		
38	8.7	8.75		
39	8.7	8.75		

Bottom/ Phyto & Zooplankton Tows

Secchi Disc Transparency depth - 10 metres

1 litre water samples collected from:

Depth	Turbidity
6 m	.40
12 m	.37
28 m	.30

Vertical Phytoplankton Tows - net mesh 80 u - from: 12 m, 39 m

Vertical Zooplankton Tows - net mesh - 116 u - from: 12 m, 39 m

Lake Station #4 - Lower Arrow Lake

Location: mid-lake 4100 metres from dam face

TEMPERATURE & DISSOLVED OXYGEN PROFILES

Depth m	D.O. PPM	Temp. °C	Time: 1:30-2:30 PM/September 20, 1980	Sat Value	% Sat
0	8.7	15.75	Surface	9.975	87
1	8.6	15.5		10.05	86
2	8.7	14.75			
3	8.8	15.5			
4	8.7	15.5			
5	8.9	15.5		10.05	89
6	8.9	15.5			
7	8.7	15.5			
8	8.7	15.5			
9	8.7	15.5			
10	8.7	15.25		10.125	86
			Secchi Depth/	H_2O Sample	(Turbidity - .44)
11	8.8	15.0		10.2	86
12	8.8	15.0	Phyto & Zooplankton	Tows/	H_2O Sample (Turbidity - .35)
13	8.8	14.5			
14	8.8	14.0		10.4	85
15	8.8	13.75			
16	8.8	11.25			
17	8.8	10.5		11.2	79
18	8.4	10.25			
19	8.6	10.0	H_2O Sample		(Turbidity - .39)
20	8.6	10.0		11.3	76
21	8.8	10.0			
22	8.8	9.75			
23	8.8	9.5		11.45	77
24	8.8	9.25			
25	8.8	9.25			
26	8.8	9.25			
27	8.8	9.25			
28	8.8	9.0			
29	8.5	9.0			
30	8.2	9.0	Bottom/	Phyto. & Zooplankton	Tows

APPENDIX 3

Columbia River Water Quality and Flow Data During Construction of Hugh Keenleyside and Revelstoke Dams

TABLE A 3.1
SUSPENDED SOLIDS DATA: 1963 (15) CB, SB (N)

Month	Stn. 1A[1] (mg/L)	Stn. 1[2] (mg/L)	Stn. 1B[3] (mg/L)	Stn. 2[4] (mg/L)	Stn. 3[5] (mg/L)	Stn. 4[6] (mg/L)	Stn. 5[7] (mg/L)
Jan	-	-	-	-	-	-	-
Feb	-	-	-	-	-	-	-
Mar	-	-	-	-	-	-	-
Apr	-	-	-	-	-	-	-
May	-	-	-	-	-	-	-
Jun	-	-	-	-	-	-	-
Jul	-	-	-	-	-	-	-
Aug	-	-	-	-	-	-	-
Sep	-	2.0 (1)	-	1.8 (1)	2.5 (1)	3.0 (1)	2.8 (1)
Oct	-	1.9 (1)	-	2.3 (1)	2.1 (1)	2.6 (1)	2.7 (1)
Nov	-	1.9 (1)	-	2.0 (1)	2.5 (1)	2.0 (1)	1.7 (1)
Dec	-	1.6 (1)	-	1.5 (1)	2.0 (1)	2.3 (1)	1.9 (1)
Average	-	-	-	-	-	-	-

1 Upstream of BC Timber Ltd. (new intake)
2 Upstream of BC Timber Ltd. (old intake)
3 Castlegar
4 Kootenay River at Brilliant Dam
5 Kinnaird Intake
6 Upstream of Cominco Intake
7 Upstream of Pend'Oreille Confluence

TABLE A 3.2
SUSPENDED SOLIDS DATA: 1964 (15) CB, SB (N)

Month	Stn. 1A[1] (mg/L)	Stn. 1[2] (mg/L)	Stn. 1B[3] (mg/L)	Stn. 2[4] (mg/L)	Stn. 3[5] (mg/L)	Stn. 4[6] (mg/L)	Stn. 5[7] (mg/L)
Jan	-	0.9 (1)	-	0.8 (1)	1.0 (1)	1.0 (1)	0.7 (1)
Feb	-	0.7 (1)	-	0.6 (1)	0.5 (1)	0.6 (1)	0.7 (1)
Mar	-	1.0 (1)	-	0.8 (1)	0.5 (1)	0.9 (1)	1.5 (1)
Apr	-	0.5 (1)	-	0.8 (1)	1.0 (1)	1.1 (1)	0.7 (1)
May	-	0.6 (1)	-	1.0 (1)	0.5 (1)	0.1 (1)	0.9 (1)
Jun	-	1.0 (1)	-	0.7 (1)	0.8 (1)	1.2 (1)	1.3 (1)
Jul	-	2.0 (1)	-	1.5 (1)	1.4 (1)	1.0 (1)	1.6 (1)
Aug	-	2.0 (1)	-	1.5 (1)	1.4 (1)	1.5 (1)	2.0 (1)
Sep	-	1.0 (1)	-	1.5 (1)	2.1 (1)	1.2 (1)	1.0 (1)
Oct	-	0.4 (1)	-	0.5 (1)	1.0 (1)	0.4 (1)	0.5 (1)
Nov	-	1.0 (1)	-	1.3 (1)	0.4 (1)	0.7 (1)	1.8 (1)
Dec	-	1.1 (1)	-	0.5 (1)	0.4 (1)	0.6 (1)	0.7 (1)
Average	-	1.0	-	1.0	0.9	0.9	1.1

1 Upstream of BC Timber Ltd. (new intake)
2 Upstream of BC Timber Ltd. (old intake)
3 Castlegar
4 Kootenay River at Brilliant Dam
5 Kinnaird Intake
6 Upstream of Cominco Intake
7 Upstream of Pend'Oreille Confluence

TABLE A 3.3

SUSPENDED SOLIDS DATA: 1965 (15) CB, SB (N)

Month	Stn. 1A[1] (mg/L)	Stn. 1[2] (mg/L)	Stn. 1B[3] (mg/L)	Stn. 2[4] (mg/L)	Stn. 3[5] (mg/L)	Stn. 4[6] (mg/L)	Stn. 5[7] (mg/L)
Jan	-	0.5 (1)	-	0.4 (1)	1.0 (1)	0.6 (1)	0.4 (1)
Feb	-	0.5 (1)	-	0.6 (1)	0.7 (1)	1.0 (1)	0.6 (1)
Mar	-	0.9 (1)	-	0.6 (1)	0.4 (1)	0.7 (1)	0.7 (1)
Apr	-	0.7 (1)	-	0.5 (1)	0.8 (1)	0.5 (1)	0.7 (1)
May	1.2, 1.4(24)	4.8, 8.1(24)	4.7, 4.3(24)	3.7, 6.8(24)	3.4, 3.3(24)	2.1, 1.4(24)	3.3, 2.6(24)
Jun	0.6, 0.4(30)	3.2, 2.8(29)	3.6, 3.5(30)	2.0, 1.4(30)	2.7, 2.3(30)	2.6, 1.9(30)	2.2, 1.5(30)
Jul	0.9, 0.6(18)	8.3, 2.2(28)	10.0, 5.7(18)	3.7, 2.6(18)	8.6, 5.3(18)	6.8, 3.4(18)	6.5, 4.0(18)
Aug	1.4, 0.8(28)	4.9, 2.2(28)	5.3, 5.1(28)	1.3, 1.0(28)	6.2, 8.6(28)	4.8, 3.8(28)	4.8, 3.1(28)
Sep	1.5, 0.4(30)	39.3, 23.8(30)	39.6, 18.9(30)	1.9, 0.4(30)	33.0, 17.4(30)	27.2, 18.8(30)	27.6, 18.4(30)
Oct	1.4, 1.9(18)	32.0, 22.3(18)	22.8, 21.5(18)	1.0, 0.4(18)	12.9, 9.3(18)	12.7, 9.6(18)	13.9, 8.6(16)
Nov	1.1, 0.7(5)	12.6, 8.5(5)	19.2, 10.2(5)	1.0, 0.4(5)	12.7, 7.7(5)	8.0, 4.7(5)	- -
Dec	1.0, 0.6(5)	20.2, 17.2(5)	15.2, 10.5(5)	0.7, 0.5(5)	7.9, 3.7(5)	10.4, 8.9(5)	- -
Average	-	10.7	-	1.5	7.5	6.5	6.1

[1]Upstream of BC Timber Ltd. (new intake)

[2]Upstream of BC Timber Ltd. (old intake)

[3]Castlegar

[4]Kootenay River at Brilliant Dam

[5]Kinnaird Intake

[6]Upstream of Cominco Intake

[7]Upstream of Pend'Oreille Confluence

TABLE A 3.4

SUSPENDED SOLIDS DATA: 1966 (15) CB, SB (N)

Month	Stn. 1A[1] (mg/L)	Stn. 1[2] (mg/L)	Stn. 1B[3] (mg/L)	Stn. 2[4] (mg/L)	Stn. 3[5] (mg/L)	Stn. 4[6] (mg/L)	Stn. 5[7] (mg/L)
Jan	1.4, 1.0 (4)	25.3, 20.3 (4)	33.1, 26.3 (4)	0.7, 0.4 (4)	14.3, 10.0 (4)	11.5, 12.5 (4)	- -
Feb	1.6, 0.7 (5)	9.5, 3.9 (5)	9.1, 2.9 (5)	0.7, 0.3 (4)	5.1, 1.5 (4)	6.0, 14.0 (5)	- -
Mar	2.5, 3.0 (4)	11.1, 2.4 (4)	12.9, 2.1 (4)	- -	- -	4.2, 0.6 (4)	- -
Apr	3.4, 2.3 (5)	5.4, 2.7 (5)	8.7, 3.0 (5)	- -	- -	3.5, 0.8 (2)	- -
May	0.9, 0.2 (4)	13.5, 8.9 (4)	12.8, 4.0 (4)	- -	- -	- -	- -
Jun	1.0, 0.4 (4)	23.2, 14.7 (4)	17.9, 6.8 (4)	- -	- -	- -	- -
Jul	1.5, 0.7 (4)	12.6, 10.6 (4)	11.8, 9.4 (4)	- -	- -	- -	- -
Aug	1.7, 0.3 (5)	7.1, 4.0 (5)	6.4 2.7 (5)	- -	- -	- -	- -
Sep	1.5, 0.2 (4)	6.2, 0.5 (5)	4.7, 0.8 (5)	- -	- -	- -	- -
Oct	1.4, 0.2 (6)	6.5, 0.5 (5)	6.1, 0.8 (5)	- -	- -	- -	- -
Nov	1.5, 0.1 (4)	5.7, 0.6 (4)	6.0, 0.4 (4)	- -	- -	- -	- -
Dec	1.2, 0.3 (3)	2.3, 1.3 (3)	3.1, 2.3 (3)	- -	- -	- -	- -
Average	1.6	10.7	11.1	-	-	-	-

1 Upstream of BC Timber Ltd. (new intake)
2 Upstream of BC Timber Ltd. (old intake)
3 Castlegar
4 Kootenay River at Brilliant Dam
5 Kinnaird Intake
6 Upstream of Cominco Intake
7 Upstream of Pend'Oreille Confluence

TABLE A 3.5
SUSPENDED SOLIDS DATA: 1967 (15) CB, SB (N)

Month	Stn. 1A[1] (mg/L)	Stn. 1[2] (mg/L)	Stn. 1B[3] (mg/L)	Stn. 2[4] (mg/L)	Stn. 3[5] (mg/L)	Stn. 4[6] (mg/L)	Stn. 5[7] (mg/L)
Jan	L0.1 (1)	L0.1 (1)	L0.1 (1)	-	-	-	-
Feb	1.5, 0.1 (4)	2.6, 0.7 (4)	3.2, 0.7 (4)	- -	- -	- -	- -
Mar	1.6, 0.6 (4)	3.8, 1.7 (4)	3.3, 1.3 (4)	- -	- -	- -	- -
Apr	11.0 (1)	33.0 (1)	12.5 (1)	-	-	-	-
May	1.8, 0.1 (5)	2.1, 0.2 (5)	2.5, 0.3 (5)	- -	- -	- -	- -
Jun	2.1, 0.1 (2)	2.5, 0.1 (2)	2.5, 0.1 (2)	- -	- -	- -	- -
Jul	3.2, 2.0 (3)	3.6, 1.9 (3)	3.6, 1.7 (3)	- -	- -	- -	- -
Aug	4.0, 0.0 (2)	4.9, 0.1 (2)	5.8, 0.4 (2)	- -	- -	- -	- -
Sep	-	-	-		-	-	-
Oct	2.0 (1)	2.5 (1)	3.0 (1)	-	-	-	-
Nov	3.0 (1)	6.0 (1)	11.5 (1)	-	-	-	-
Dec	1.0 (1)	3.0 (1)	10.5 (1)	-	-	-	-
Average	2.8	5.8	5.3	-	-	-	-

1 Upstream of BC Timber Ltd. (new intake)

2 Upstream of BC Timber Ltd. (old intake)

3 Castlegar

4 Kootenay River at Brilliant Dam

5 Kinnaird Intake

6 Upstream of Cominco Intake

7 Upstream of Pend'Oreille Confluence

L = Less than

TABLE A 3.6
SUSPENDED SOLIDS DATA: 1968 (15) CB, SB (N)

Month	Stn. 1A[1] (mg/L)	Stn. 1[2] (mg/L)	Stn. 1B[3] (mg/L)	Stn. 2[4] (mg/L)	Stn. 3[5] (mg/L)	Stn. 4[6] (mg/L)	Stn. 5[7] (mg/L)
Jan	3.0 (1)	13.0 (1)	3.0 (1)	-	-	-	-
Feb	2.0 (1)	4.0 (1)	3.0 (1)	-	-	-	-
Mar	3.0 (1)	3.0 (1)	3.0 (1)	-	-	-	-
Apr	12.0 (1)	18.0 (1)	2.0 (1)	-	-	-	-
May	2.0 (1)	2.0 (1)	3.0 (1)	-	-	-	-
Jun	1.0 (1)	18.0 (1)	8.0 (1)	-	-	-	-
Jul	3.0 (1)	2.0 (1)	10.0 (1)	-	-	-	-
Aug	-	-	-	-	-	-	-
Sep	-	-	-	-	-	-	-
Oct	-	-	-	-	-	-	-
Nov	-	-	-	-	-	-	-
Dec	-	-	-	-	-	-	-
Average	-	-	-	-	-	-	-

1 Upstream of BC Timber Ltd. (new intake)
2 Upstream of BC Timber Ltd. (old intake)
3 Castlegar
4 Kootenay River at Brilliant Dam
5 Kinnaird Intake
6 Upstream of Cominco Intake
7 Upstream of Pend'Oreille Confluence

A 2.3

Plume Study

September 19, 1980

August 12, 1980

Summary of Effluent Dispersion Models

TABLE A 3.8

AVERAGE MONTHLY FLOW DATA: 1964 (18)

Month	Columbia R. at Castlegar ($\times 10^7$ m^3/d)	Kootenay R. at Castlegar[1] ($\times 10^7$ m^3/d)	Columbia R. as Birchbank ($\times 10^7$ m^3/d)
Jan	2.44	3.25	5.69
Feb	2.03	2.47	4.50
Mar	1.81	2.56	4.36
Apr	2.40	3.97	6.38
May	8.24	12.84	21.08
Jun	30.76	29.29	60.05
Jul	35.25	18.75	54.00
Aug	19.79	7.52	27.30
Sep	10.11	3.54	13.65
Oct	10.11	4.49	14.60
Nov	5.92	3.67	9.59
Dec	3.52	2.75	6.26
Average	11.06	8.00	19.01

1 Calculated difference between monthly values at Birchbank and Castlegar

TABLE A 3.9
AVERAGE MONTHLY FLOW DATA: 1965 (18)

Month	Columbia R. at Castlegar ($\times 10^7$ m^3/d)	Kootenay R. at Castlegar[1] ($\times 10^7$ m^3/d)	Columbia R. as Birchbank ($\times 10^7$ m^3/d)
Jan	2.51	2.95	5.46
Feb	2.23	3.40	5.62
Mar	2.12	4.22	6.33
Apr	3.13	6.03	9.16
May	11.40	15.64	27.04
Jun	27.30	25.14	52.44
Jul	26.61	14.86	41.47
Aug	21.08	7.26	28.34
Sep	10.20	3.11	13.31
Oct	5.88	3.63	9.50
Nov	5.82	3.42	9.24
Dec	3.60	2.65	6.26
Average	10.20	7.69	17.88

1 Calculated difference between monthly values at Birchbank and Castlegar

TABLE A 3.10
AVERAGE MONTHLY FLOW DATA: 1966 (18)

Month	Columbia R. at Castlegar ($\times 10^7$ m^3/d)	Kootenay R. at Castlegar[1] ($\times 10^7$ m^3/d)	Columbia R. as Birchbank ($\times 10^7$ m^3/d)
Jan	2.57	2.90	5.47
Feb	2.23	2.89	5.11
Mar	1.98	3.91	5.89
Apr	4.03	7.12	11.15
May	13.48	16.24	29.72
Jun	29.38	25.83	55.21
Jul	29.89	15.98	45.88
Aug	19.87	5.27	25.14
Sep	10.97	2.85	13.82
Oct	7.36	2.92	10.28
Nov	4.67	3.19	7.85
Dec	3.42	2.48	5.90
Average	10.89	7.63	18.49

1 Calculated difference between monthly values at Birchbank and Castlegar

TABLE A 3.11
AVERAGE MONTHLY FLOW DATA: 1967 (18)

Month	Columbia R. at Castlegar ($\times 10^7$ m^3/d)	Kootenay R. at Castlegar[1] ($\times 10^7$ m^3/d)	Columbia R. as Birchbank ($\times 10^7$ m^3/d)
Jan	2.86	3.40	6.26
Feb	2.50	5.05	7.55
Mar	2.11	2.89	4.99
Apr	2.58	3.92	6.51
May	8.90	12.01	20.91
Jun	37.50	34.65	72.14
Jul	37.07	20.56	57.63
Aug	20.65	6.91	27.56
Sep	12.87	2.85	15.72
Oct	7.92	3.91	11.84
Nov	5.19	3.53	8.73
Dec	3.24	5.66	8.90
Average	12.01	8.78	20.82

1 Calculated difference between monthly values at Birchbank and Castlegar

TABLE A 3.12

AVERAGE MONTHLY FLOW DATA: 1968 (18)

Month	Columbia R. at Castlegar ($\times 10^7$ m^3/d)	Kootenay R. at Castlegar[1] ($\times 10^7$ m^3/d)	Columbia R. as Birchbank ($\times 10^7$ m^3/d)
Jan	2.44	2.87	5.30
Feb	2.61	3.94	6.55
Mar	2.95	5.36	8.30
Apr	3.35	4.03	7.39
May	10.89	11.92	22.81
Jun	30.33	23.50	53.83
Jul	31.45	14.69	46.14
Aug	17.97	7.43	25.40
Sep	11.75	4.15	15.90
Oct	6.32	4.40	10.71
Nov	4.22	4.09	8.31
Dec	3.35	5.08	8.43
Average	10.63	7.62	18.32

1 Calculated difference between monthly values at Birchbank and Castlegar

TABLE A 3.13
WATER QUALITY AND FLOW DATA - REVELSTOKE DAM

	Date	Conc. S.S.[1]	Average Daily Flow[2]
Preconstruction	4 Jun 75	39	6.80
	29 Jul 75	86	7.21
	10 Feb 76	3	1.40
Construction	5 Jan 77	6	5.33
	23 Feb 77	11	5.24
	3 May 77	20	7.53
	2 Nov 77	7	4.73
	13 Feb 78	3	4.53
	27 Apr 78	151	3.67
	28 Jun 78	42	12.18
	15 Nov 78	18	3.23
	20 Feb 79	7	5.58
	10 May 79	16	4.45
	8 Aug 79	8	11.49
	19 Feb 80	7	5.99
	9 Apr 80	14	6.16
	24 Jun 80	17	7.81
	12 Aug 80	12	9.85
	7 Oct 80	7	1.96

1 Sampling Stn. near Revelstoke

2 Flows Measured at Steamboat

APPENDIX 4

TERMS OF REFERENCE

FOR

ENVIRONMENTAL STUDIES
FOR THE PROPOSED
MURPHY CREEK
HYDROELECTRIC PROJECT

BRITISH COLUMBIA HYDRO AND POWER AUTHORITY

TERMS OF REFERENCE
FOR
ENVIRONMENTAL STUDIES
FOR THE
PROPOSED MURPHY CREEK
HYDROELECTRIC PROJECT

Draft No. 2
February 1980

SYSTEM ENGINEERING DIVISION

TERMS OF REFERENCE
FOR ENVIRONMENTAL STUDIES FOR THE PROPOSED
MURPHY CREEK HYDROELECTRIC PROJECT

CONTENTS

Section	Subject	Page
1.0	INTRODUCTION	2
2.0	STUDIES AREA	3
3.0	STUDIES OBJECTIVES	3
4.0	STUDIES ORGANIZATION	4
5.0	STUDIES METHODOLOGY	6
6.0	REPORTING PROCEDURES	7
7.0	STUDIES SCHEDULE	8
8.0	STUDIES SECTIONS	8

A. Geology and Landforms
B. Hydrology and River Morphology
C. Water Quality
D. Climate
E. Agriculture
F. Vegetation
G. Forestry
H. Wildlife
I. Fish and Aquatic Habitats
J. Regional Economy and Human Communities
K. Recreation and Tourism
L. Heritage Resources
M. Resource Analysis

1.0 INTRODUCTION

These Terms of Reference are for detailed ecological and socio-economic studies, called the "Studies", which are required for environmental impact evaluation of a potential hydroelectric development by the British Columbia Hydro Electric and Power Authority (B.C. Hydro) on the Columbia River in the vicinity of Murphy Creek.

Prior to signing the Columbia River Treaty in 1961 and its retification in 1964, numerous studies were made of the hydroelectric development of the Columbia River in Canada. The Treaty between the United States and Canada led to the construction of Mica, Hugh Keenleyside and Duncan projects in Canada. Other major hydroelectric projects in the Columbia River basin in Canada include the Kootenay Canal project completed in 1975, and the Seven Mile and Revelstoke projects which are under construction.

The potential of the Murphy Creek site was first identified in 1956. Consideration of the development of the project was more recently given during the 1972 B.C. Energy Board studies. Sugsequently, preliminary engineering and environmental studies were carried out in 1977 and 1978, to examine the project potential at a prefeasibility level and to identify probable environmental impacts.

The Murphy Creek site is located on the Columbia River approximately 3 km upstream of the city of Trail and 25 km downstream of the confluence of the Columbia and Kootenay rivers. The tentative layout for the project consists of an earthfill dam, approximately 33 m high, extending across the river from the left bank to a concrete spillway and 10-unit powerhouse located on the right bank. A total installed capacity of 400 MW would be provided by ten 40 MW turbine generators.

In early 1979 a preliminary study of the residential, commercial and industrial properties that may be affected by the project was undertaken by the Properties Division. An engineering feasibility study scheduled for completion by the end of 1980 is in progress.

All field work associated with the Studies outlined in these Terms of Reference is scheduled for completion in 1980 where possible, in order that environmental impacts may be properly assessed by mid-1981. The eingineering feasibility study associated with the project is being carried out by the Hydroelectric Generation Projects Division of B.C. Hydro, who will also be responsible for several aspects of the Studies such as geology, hydrology and river morphology.

2.0 STUDIES AREA

The Studies area consists of all lands on either side of the Columbia River from the axis of the proposed dam in the vicinity of Oasis, upstream to the Hugh Keenleyside dam on the Columbia River, and to the Brilliant dam on the Kootenay River, up to an elevation of 500 m. Studies may extend beyond this area in specific cases where considered necessary.

Some areas outside these limits will be studies for socio-economic impacts from both the construction work force and the operating staff.

3.0 STUDIES OBJECTIVES

1. To provide an inventory of environmental resources that could be impacted by the potential project within the Studies area. This will be compiled from on-site investigations and other available sources.

2. To provide a qualitative and quantitative evaluation of impacts, both adverse and beneficial, which would result from the potential project.

3. To provide an evaluation of resource losses and gains in monetary terms for inclusion in a benefit-cost analysis.

4. To provide data which could be needed for preparation of an Environmental Impact Statement for the potential project.

4.0 STUDIES ORGANIZATION

(a) Co-ordination

The entire program will be directed and co-ordinated either by B.C. Hydro, or by B.C. Hydro assisted by a prime consultant. Under this direction, certain disciplines of the Studies will be carried out by B.C. Hydro staff or by consultants. Technical responsibility within individual disciplines will rest with the B.C. Hydro staff or with respective consultants. B.C. Hydro or its prime consultant will assume the role of co-ordinating the individual disciplines during the Studies period and during the preparation of the final report.

Consultants should liaise with the appropriate government agencies both before and during their studies to ensure that full use is made of existing available information and knowledge.

Consultants, subconsultants and their staff shall co-operate with all other consultants hired by B.C. Hydro for the same or similar projects, and on request by B.C. Hydro shall make available to such consultants all material gathered or produced for this project.

All contact with outside agencies and the public shall be co-ordinated through B.C. Hydro.

(b) Studies Sections

The Studies shall be organized into four groups: Physical Resources, Terrestrial Resources, Aquatic Resources and Socio-economic. Each group is composed of closely related subjects called "Sections" A to L, as follows:

Physical Resources

A Geology and Landforms

B Hydrology and River Morphology

C Water Quality

D Climate

Terrestrial Resources

E Agriculture

F Vegetation

G Forestry

H Wildlife

Aquatic Resources

I Fish and Aquatic Habitats

Socio-economic

J Regional Economy and Human Communities

K Recreation and Tourism

L Heritage Resources

M Resource Analysis

5.0 STUDIES METHODOLOGY

Evaluation of the environmental impact of the project shall take into consideration all project actions associated with the development. These shall include pre-project activities such as field investigation or land acquisition; construction activities such as site and reservoir clearing, dam, powerhouse and road construction, construction camp activities; and operation and maintenance of the powerplant. Project descriptions will be provided by B.C. Hydro.

Definition and development of all methodologies for the Studies should be made early in the program and provided to B.C. Hydro for their approval. This may include the use of various impact matrices, mapping techniques, economic analyses, etc. The methodology for evaluation in each of the Sections shall be consistent with criteria selected for the evaluation of the environmental impact. Special attention shall be directed to providing information suitable for inclusion in a benefit-cost analysis of mitigation and compensation alternatives.

The following is provided by B.C. Hydro to give direction on the scope of the Studies.

1. All resources and their significance, with and without the project, on a local, regional and provincial scale based upon present value and potential value.

2. Environmental impacts including:
   a. Primary, secondary and induced impacts.
   b. Beneficial and adverse effects.

3. Distribution aspects of impacts including:
   a. Geographical - local, regiona, provincial and international.
   b. Social - impacts on various segments of the population, ethnic or special interest groups.
   c. Transfer of resource demands to other locations.

4. Probability of occurrence of an impact and reasons for undertainty of the impact's occurrence.

5. Expected time and duration of an impact occurrence. A distinction shall be made between short-term impacts (those with last for the construction period only) and long-term impacts (those which persist after construction).

6. Possible benefits, both short and long-term , of all compensation and mitigation measures.

7. The costs associated with all compensation and mitigation measures.

8. Relationship between project impacts and long-term regional development prospects shall be evaluated.

All sources of data, information and references shall be thoroughly documented.

6.0 REPORTING PROCEDURES

Written reports will be required for all Sections of th Studies. The number of copies of such reports will be established at the time study proposals are colled for. Prior to the preparation of these reports, consultants will be required to submit a report outline to B.C. Hydro for review and approval. Subsequently, draft reports will be prepared and submitted for review and approval by B.C. Hydro and, where necessary, by outside experts before they are accepted. All final reports shall be in a form suitable for release to government agencies and the public.

Following completion of all the reports for the Sections, B.C. Hydro or its prime consultant will prepare an integrated summary report in consultation with the authors of the Sections and outside experts, where necessary. This report will be the final report of the Studies.

7.0 STUDIES SCHEDULE

The Studies will be undertaken in 1980 and possibly beyond. A target schedule showing specific deadlines will be issued for each Section.

8.0 STUDIES SECTIONS

The following are guidelines for each of the Sections. These guidelines distinguish between inventory and assessment work and, where feasible, this distinction should be made in report preparation.

POOR

QUALITY

ORIGINAL